

Durham Research Online

Deposited in DRO:

06 September 2010

Version of attached file:

Published Version

Peer-review status of attached file:

Peer-reviewed

Citation for published item:

Schreve, D. C. and Harding, P. and White, M. J. and Bridgland, D. R. and Allen, P. and Clayton, F. and Keen, D. H. and Penkman, K. E. H (2006) 'A Levallois knapping site at West Thurrock, Lower Thames, UK : its quaternary context, environment and age.', Proceedings of the Prehistoric Society., 72 . pp. 21-52.

Further information on publisher's website:

<http://www.prehistoricsociety.org/>

Publisher's copyright statement:

Use policy

The full-text may be used and/or reproduced, and given to third parties in any format or medium, without prior permission or charge, for personal research or study, educational, or not-for-profit purposes provided that:

- a full bibliographic reference is made to the original source
- a [link](#) is made to the metadata record in DRO
- the full-text is not changed in any way

The full-text must not be sold in any format or medium without the formal permission of the copyright holders.

Please consult the [full DRO policy](#) for further details.

A Levallois Knapping Site at West Thurrock, Lower Thames, UK: its Quaternary Context, Environment and Age

By D.C. SCHREVE¹, P. HARDING², M.J. WHITE³, D.R. BRIDGLAND⁴, P. ALLEN¹, E. CLAYTON⁵,
D.H. KEEN⁶ and K.E.H. PENKMAN⁶

This paper is dedicated to the memory of our friend and colleague David Keen

Levallois knapping debris is present beneath the sides of a disused tramway cutting connected to Lion Pit, West Thurrock, Essex. This occurrence, first recorded during the early 20th century, is in the basal gravel of the Taplow/Mucking Formation, which dates from the end of Marine Oxygen Isotope Stage (MIS) 8. The relatively undisturbed nature of this knapping debris is confirmed by the incidence of refitting material, although finer debitage is absent, presumably winnowed out. The Levallois character of the assemblage is demonstrated by the occurrence of characteristic 'tortoise' cores and flakes with faceted striking platforms. The artefact-bearing gravel is overlain by >10 m of predominantly fine-grained sediments, including fossiliferous sands and massive clayey silt, as well as laminated silts, clays, and sands of possible estuarine origin. These are attributed to deposition under temperate conditions during MIS 7. To the south, a younger fluvial gravel, attributed to MIS 6, has been incised into the interglacial sequence. The top of the estuarine sequence has been affected by pedogenesis, both before and after its burial by an unbedded solifluction gravel.

INTRODUCTION

The existence of a rich Palaeolithic site in the side of a tramway cutting leading into one of many chalk quarries (the Lion Pit) at West Thurrock has been known since the early years of the 20th century (Hinton & Kennard 1900; Dibley & Kennard 1916; Warren 1923a; 1923b). The cutting (TQ 598783) lies on the west side of the parish of Thurrock, approximately 1 km north of the River Thames (Fig. 1) and was originally created to transport chalk raw material to cement works and riverside wharves.

Much of the natural topography of the area is unrecognisable, having been extensively altered by chalk and gravel quarrying. The former workings are now used primarily for residential and commercial purposes, although the vegetated and partly flooded Lion Pit chalk quarry is conserved as a biological Site of Special Scientific Interest (SSSI; the Grays Thurrock Chalk Pit SSSI). The disused cutting was for many years overgrown and used for fly-tipping (Bridgland *et al.* 2003), although a path has recently been constructed along its floor and the vegetation cut back in places, thereby substantially improving access.

Flint artefacts, shells, and bones were reported by Abbott (1890) from the West Thurrock Tunnel Cement Works quarry, which was situated 2.5 km to the west of the Lion Pit section at TQ 575777 (Fig. 1). Although lost for many years, the large mammal remains collected by Abbott from deposits overlying a basal gravel were eventually rediscovered in 1974 in the Wellcome Institute for the History of Medicine, London (now transferred to the Natural History Museum), and were described by Carreck (1976).

¹Department of Geography, Royal Holloway, University of London, Egham, Surrey, TW20 0EX, UK.

²Wessex Archaeology, Portway House, Old Sarum Park, Salisbury, Wiltshire SP4 6EB, UK.

³Department of Archaeology, University of Durham, Science Laboratories, South Road, Durham, DH1 3LE, UK.

⁴Department of Geography, University of Durham, Science Laboratories, South Road, Durham, DH1 3LE, UK.

⁵18 Scrivens Mead, Thatcham, Berkshire, RG19 4FQ, UK

⁶BioArch, Biology S Block, University of York, PO Box 373, York, YO10 5YW, UK.

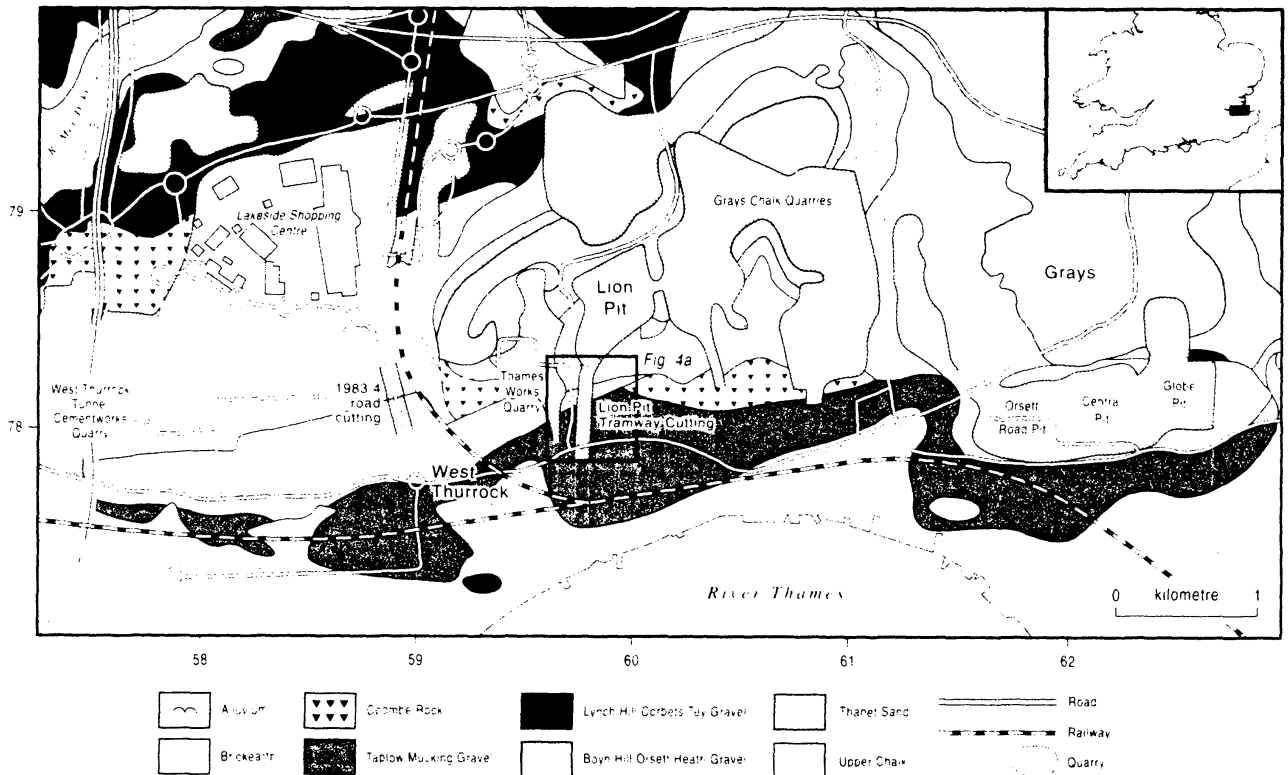


Fig. 1.

Location of the Lion Pit tramway cutting within the complex of former mineral workings in the Grays area (extended from Bridgland 1994, fig. 4.21). The inset shows location within SE England

Additional vertebrate material collected at the turn of the 20th century includes remains of aurochs, rhinoceros, and elephant recovered by Hinton and Kennard (1900) from a section of bedded sand with loam in Gibb's Chalk Quarry on the London Road, West Thurrock (Whitaker 1889), immediately south of the Lion tramway cutting, and finds of woolly mammoth, aurochs, and horse from 'brickearth' banked against a buried Chalk cliff at the Thames Works Quarry, 500 m west of the Lion Pit (Hinton 1901; Fig. 1).

In the early years of the 20th century, a Palaeolithic 'working floor' was discovered at the Lion Pit by A.S. Kennard in 'Middle Terrace deposits against a chalk cliff' (Dibley & Kennard 1916). Warren (1923a; 1923b) subsequently referred to a rich assemblage of tortoise cores and Levallois flakes in the basal gravel at West Thurrock as a 'proto-Mousterian industry'

but later described it as a 'mid-Levallois working site' (Warren 1942). Warren and Kennard amassed a small collection of worked flints from this site, which eventually found their way into the British Museum. Despite the importance of this lithic assemblage, no full description of the Lion Pit site was ever published and, with the exception of work by Hollin (1977), it was largely overlooked for several decades, greater attention being given to other Levallois sites in the Lower Thames at Northfleet (Smith 1911; 1923; Burchell 1933; Dewey 1932), Crayford (Kennard 1944; Wymer 1968; Roe 1981), and Purfleet (Wymer 1968, 1985; Palmer 1975; Hollin 1977).

Fortunately the West Thurrock tramway cutting had been included by the Nature Conservancy in its earliest listings of geological SSSIs, thanks to direct communication between Warren and W.A. Macfadyen, the Nature Conservancy's first geologist.

Indeed, record cards dating back to MacFadyen on file with the successor organisation, the Nature Conservancy Council (NCC), contained precise details, supplied by Warren, of the location of the 'working floor'. When the NCC initiated a review of its geological SSSI coverage at the end of the 1970s, Warren's notes enabled re-excavation of the overgrown sections to be precisely directed towards the rediscovery of the artefact-bearing deposits, work undertaken as part of the Geological Conservation Review project (Bridgland 1985; Bridgland & Harding 1994; 1995). As well as exposing, sampling, and recording the extensive sequence of Quaternary sediments at the site, it was also possible to conduct a small controlled excavation of the main archaeological levels, once these had been identified. A geological report of this work, which took place in April 1984, was provided by Bridgland and Harding (1994). Two additional sections (nos 2 & 3; Fig. 2) were investigated further south in the cutting, revealing weathered silty clay (brickearth) and an overlying gravel, as previously described by Hollin (1977). The site was reopened in October 1995 for an excursion visit by the Quaternary Research Association, for which another small section was cut in the archaeological levels by controlled excavation. New exposures (Sections 4, 5, & 6) were opened up further south, providing samples of unoxidised brickearth for palaeontological study. This is equivalent to the fossiliferous West Thurrock brickearth described by Whitaker (1889) and Abbott (1890). Sections 3 and 4 were covered up during work to stabilise the cutting sides in the 1990s although, in 2003, a new temporary exposure (Section 7) became available during similar work, allowing a new study of the brickearth and the beds immediately above and below it.

Differences between the faunal and archaeological assemblages from West Thurrock and the neighbouring Essex sites of Grays Thurrock (Morris 1836) and Little Thurrock (Bridgland & Harding 1993) were recognised at an early stage by Hinton (1910), Kennard (1916), and Warren (1923a), all of whom concluded that the former was significantly younger than the latter two. However, palynological studies subsequently failed to differentiate between them and all three localities have been ascribed to the Ipswichian Interglacial (eg, West 1969; Carreck 1972; 1976; Hollin 1977; Gibbard *et al.* 1988; Gibbard 1994; 1995). Most recently, the West Thurrock interglacial

sediments have been attributed to Marine Oxygen Isotope Stage (MIS) 7, primarily on the basis of their stratigraphical and topographical position within the Lower Thames terrace staircase (Bridgland & Harding 1994; 1995). Sedimentological, palaeontological, and archaeological support for this correlation will be demonstrated below.

GEOLOGICAL CONTEXT

The deposits at West Thurrock form part of the Mucking Formation of the Lower Thames, the downstream equivalent of the Taplow Formation (and terrace) of the Middle Thames (Bridgland 1988; 1994; Fig. 3). The sequence has been exposed at a number of different locations and comparable sections of fossiliferous river terrace sands and silty clays ('brickearths'), under- and overlain by gravel and resting against a buried Chalk cliff, were described by Whitaker (1889), Abbott (1890), Hinton and Kennard (1900) and Hinton (1901). The Chalk cliff at Lion Pit lies slightly further north than further upstream (West Thurrock cemetery: TQ 588780) or downstream (Hogg Lane, Grays: TQ 610780), in a minor embayment in the north side of the palaeo-valley.

The Lion Pit tramway cutting was first re-excavated and described by Hollin (1977), who recorded a Chalk cliff rising from 6 to 16 m OD and apparently passing below Ordnance Datum beneath the terrace deposits to the south. Near the cliff, the terrace sequence comprises 9 m of sand, overlain first by 2 m of brickearth containing molluscs and ostracods, and finally by an upper sand to an elevation of 15 m OD. These deposits were seen to rise towards the cliff, with the entire section capped by colluvial deposits ('trail') (Hollin 1977). In 1983–4, a new road cutting (TQ 590780) 0.9 km to the west of the tramway cutting (Fig. 1) provided similar sections banked against Chalk on the southern side of the Purfleet Anticline. The deposits comprised a massive bed of sand that was proved from 6.5 m OD (the road surface) to 7.9 m OD, where it was overlain by c. 2.5 m of grey clayey silt, its upper two-thirds oxidised to brown. Above the silt was a further sand bed, which was in turn overlain by a gravelly, clayey sand of probable colluvial origin (Bridgland 1994). The unoxidised part of the brickearth yielded restricted pollen spectra (Gibbard 1994; see below). To the south, the deposits were unconformably overlain by a

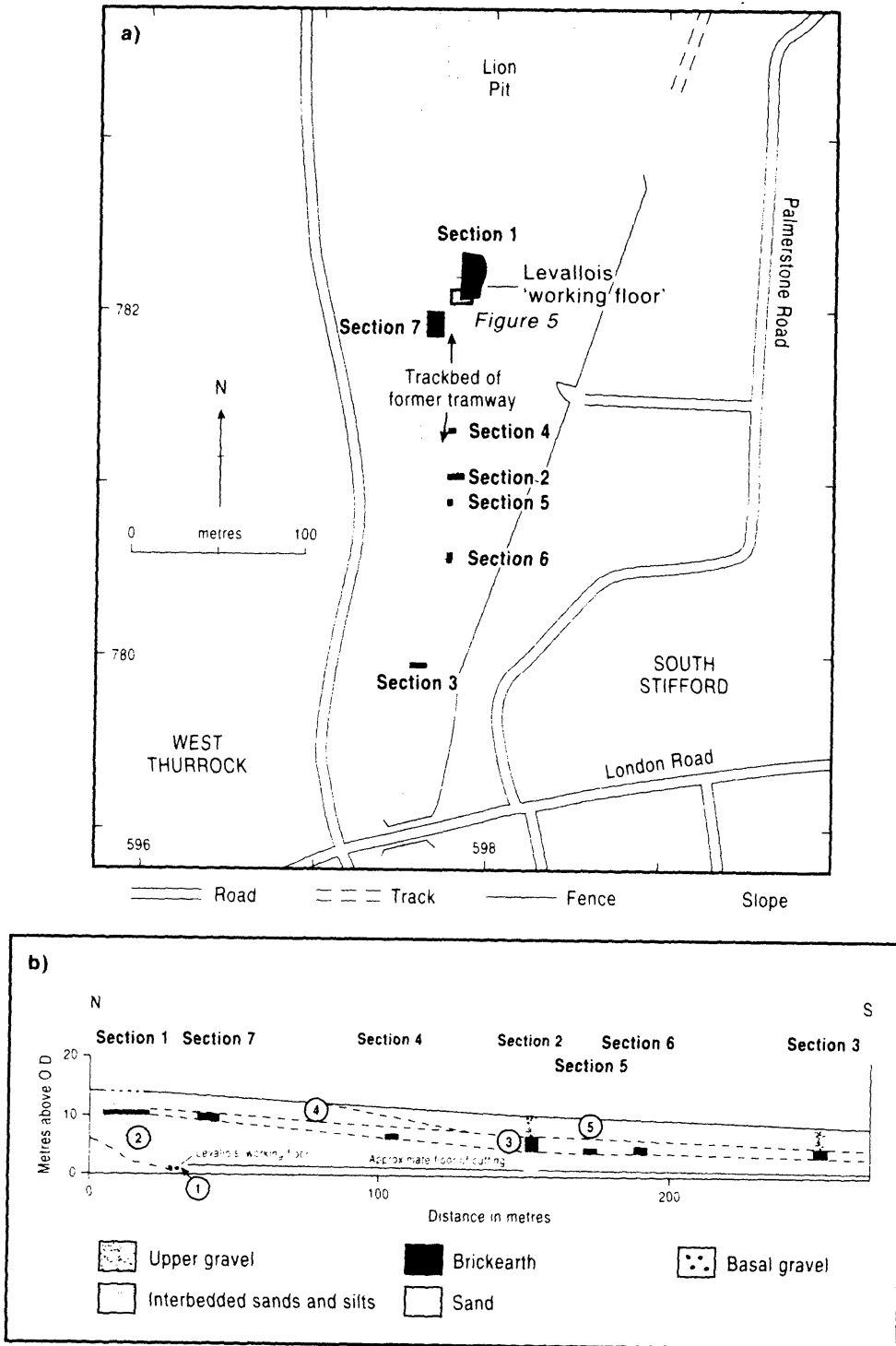


Fig. 2.

A: Location of the various sections along the Lion Pit tramway cutting. B: Longitudinal section along the cutting, showing stratigraphical relations and the locations of sections. Bed numbers are shown (circled). Modified from Bridgland & Harding (1994; 1995)

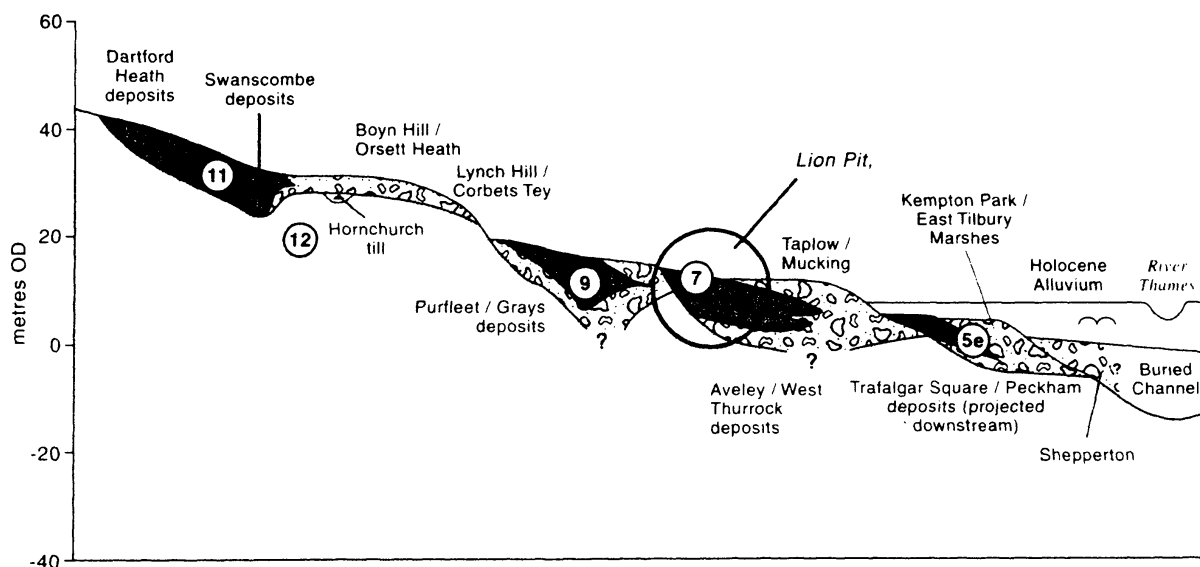


Fig. 3.

Idealised transverse section showing the stratigraphical position of the Lion Pit sediments within the Lower Thames terrace staircase. Circled numbers represent MIS attributions. Modified from Bridgland (1994, fig. 4.3)

well-bedded medium to coarse sandy gravel, ascribed to the Mucking Gravel.

The geological sequence established from the 1984 and 1995 excavations can be summarised as follows (cf. Bridgland & Harding 1994; 1995; Figs 2 & 3):

6. Colluvial overburden: unbedded gravelly, clayey sand (with palaeosol).
5. West Thurrock Gravel: present only in the southern part of the cutting (see below).
4. Upper sand: interbedded fine sands and silts, including cross-stratified and ripple laminated horizons. Particle-size analysis reveals ~85% sand (moderately well sorted). Thickness: >2.0 m.
3. Clayey silt (brickearth): unbedded and oxidised. Thickness: 0.5 m in section, increasing to > 3 m in sections further south, where it is unoxidised and sometimes shelly in its lower part. Particle-size analysis (Coulter granulometer) reveals a moderately well sorted lower clayey silt (60% silt, 30% clay, 10% sand) giving way to poorly sorted sandy clayey silt (50% silt, 25% sand, 25% clay). These analyses, using samples from Section 7 (Fig. 2), showed that previous descriptions of the 'brickearth' as a silty clay were incorrect.
2. Lower sand: coarse at the base, becoming silty and clayey in higher levels (possibly matrix introduced

from bed 3 above), where there are also small pebble 'stringers'. The unit is horizontally bedded throughout. The upper 1m (approx.) forms a distinctive clay-impregnated unit, capped with a pebbly layer. Thickness: 8.5 m.

1. Clayford Gravel: contains large, scarcely abraded flint nodules together with smaller gravel clasts in a matrix of sand. Contains Palaeolithic artefacts in mint or near-mint condition, some of which can be refitted. Thickness: up to 1.0 m.
0. 'Coombe rock': unbottomed.

Bed 0: 'Coombe rock'

At the base of the Quaternary sequence is 'coombe rock', a deposit derived by periglacial slope processes from the Chalk. This bed is assigned the number zero (0) to avoid altering the previously established numbering scheme that applied only to the fluvial sequence (Bridgland & Harding 1994, 1995). This foundation of 'coombe rock' is typical of the valley-side edges of Thames terrace deposits on Chalk and is a feature shared with the important Levallois site at Northfleet (eg, Burchell 1933; Bridgland 1994; Wenban-Smith 1995).

Bed 1: Crayford Gravel

Immediately above the 'coombe rock' is a basal fluvial gravel, which is the source of the Palaeolithic material. In this section it is up to 1 m thick, but Abbott's (1890) record from further west suggests a greater thickness, although he did not see the base of the gravel. When the gravel was removed in the controlled excavations, the top of the 'coombe rock' appeared sculpted by scouring and further modified by solution processes. The latter might have been the cause of small-scale deformation structures observed in the gravel, best seen in a thin seam of sand that divides the deposit into upper and lower divisions (Fig. 5).

The gravel is overlain by a thick sequence of sands, silts, and clays, ranging from 2 m OD to just over 13 m OD (Fig. 4). Within this sequence, three divisions (lower sand, 'brickearth', and upper sand) can be distinguished (beds 2–4), as originally observed by Hollin (1977) and similar to Abbott's (1890) section further west.

Bed 2: Lower sand

This bed comprises up to 9 m of fine and medium sand. In Section 1, its lowermost 5 m are horizontally-bedded medium sands, with obvious laminae. The upper 3.5 m are also medium sand, alternating with silty-clay laminae or beds varying from <1 cm to ?0.5 m thick, finally capped by 0.2 m of coarse pebbly sand. Occasional small ripples (<1 cm) and minor deformation structures have been noted within the upper part of the sequence. In the upper 3.5 m, the horizontal nature of the bedding is defined by the boundaries between the sand and the silty clays; primary sedimentary structures are few. Where inclined bedding was seen, it was thought to reflect undulations in the depositional surface rather than hydrodynamic bedding structures. The silty-clay partings are mostly continuous across the exposures, but several are of limited lateral extent, often continuing for a while as a stain in the adjacent sand. Occasional pebble stringers occur, usually of small (< 1 cm) flint or, rarely, chalk. Adjacent to the latter, the silty-clay was frequently calcareous. In Section 7, the topmost 1.3 m of the sand appeared massive, although a horizontal disposition of the sand was indicated by slight colour changes associated with the primary bedding (10YR 5/4, 6/4, 6/6, 6/8, 5/4 – brownish-yellow and yellowish-brown) and by occasional iron-enriched horizons a few millimetres

thick, again reflecting primary bedding. Had this section remained open longer it is possible that further drying would have revealed the clear laminae seen in the longer-lived sections.

In Section 1, the upper half of bed 2 is interbedded at the northern channel edge with four lobes of 'coombe rock' (Fig. 4). In an equivalent position in Section 7 was seen a 0.2 m bed of flints, comprising a mixture of sub-angular cobbles up to 0.15 m in diameter, often with cortex, mixed with a small amount of rounded Tertiary pebbles set in a silty sandy matrix.

There is much pseudo-bedding (wetting horizons) picked out by iron discolouration due to precipitation from groundwater. In the lower part of Section 1 these ran parallel with the 'coombe rock' surface (Fig. 4). Elsewhere, the wetting horizons formed frequent irregular patterns, particularly in Section 7. In both sections, immediately below the brickearth of bed 3, the lower sands are impregnated with clayey silt that is thought to be translocated from the brickearth. In Section 1, seams of post-depositionally translocated clay cut across the bedding. Post-depositional solution of parts of the upper two 'coombe rock' lobes in Section 1 has led to compensatory collapse and associated faulting of the overlying sediments.

Bed 3: Clayey silt (brickearth)

The clayey silt/brickearth of bed 3 is represented by only 0.5 m of oxidised clayey silt in Section 1, but the various sections (2–7) further south (Fig. 2) have revealed much greater thicknesses (up to 3 m). In sections 2, 4, and 7 it proved completely unfossiliferous, whereas poorly preserved shells and other material were recovered from sections 5 and 6. In section 6 there are brownish-black fibrous deposits on bedding planes that are suggestive of decomposed plant material (Charlotte O'Brien, pers. comm, November 2004).

In Section 7, in which the most recent study was undertaken, Bed 3 was 2.1 m thick. The lowermost 1.4 m was brecciated, predominantly grey (10YR5/1, 5Y5/1), grey-brown (10YR5/6), or brown (10YR4/3, 5/4, 7.5YR5/6, 5/8), often mottled. There were occasional calcium carbonate concretions, precipitated post-depositionally from groundwater. The colour differences and the disposition of the mottling suggest that the deposit was horizontally bedded. Above the

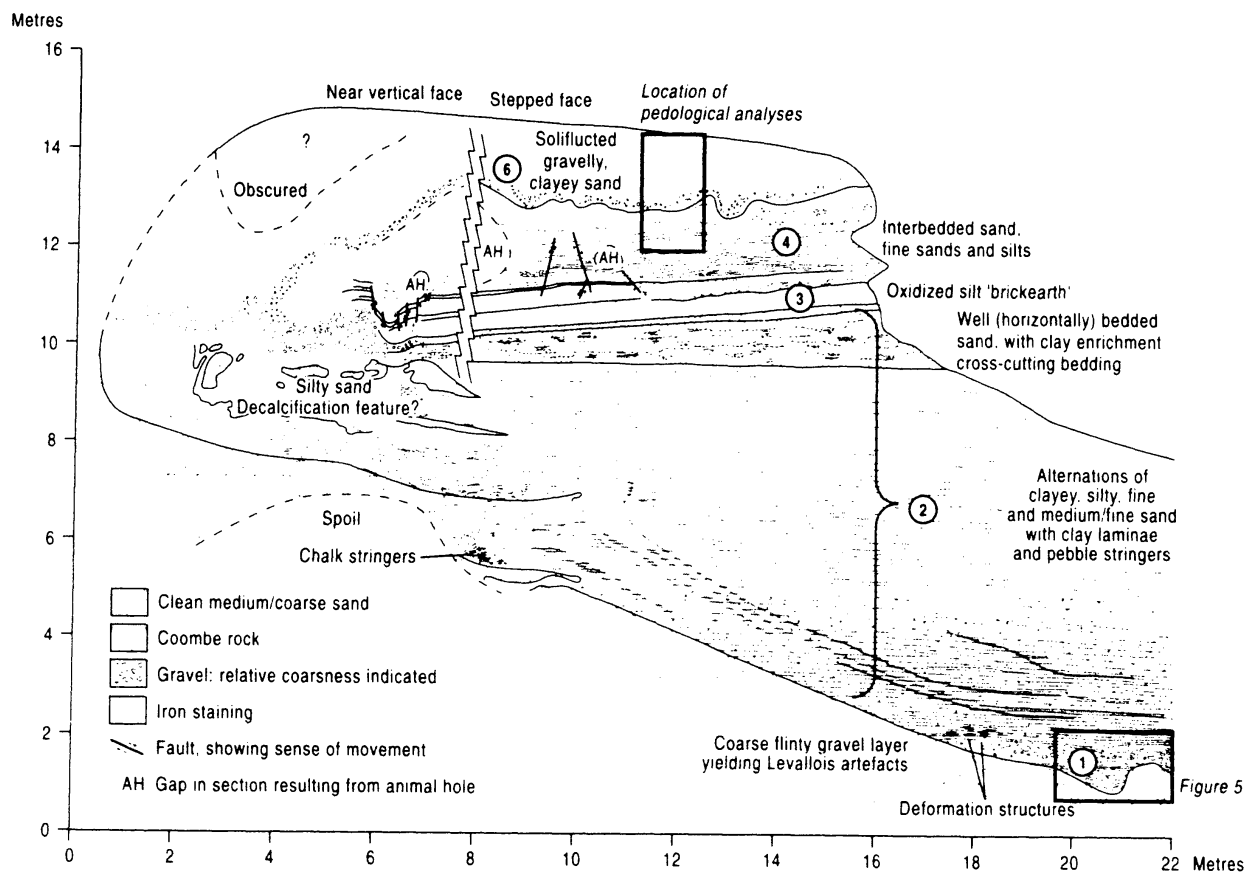


Fig. 4.

Lion Pit tramway cutting Section 1, showing the stratigraphical locations of the artefact-bearing basal deposits (see also Fig. 5) and of the pedological analyses from the uppermost levels. Bed numbers are shown (circled). Modified from Bridgland & Harding (1994; 1995)

brecciated horizons were up to 0.2 m of medium sand, highly deformed by load structures and water escape structures such that its base was highly irregular. The upper surface was planar with a slight undulation. The topmost 0.5 m of the bed comprised horizontally bedded laminated clayey silt, yellowish-brown to strong brown (10YR5/4 + 7.5YR5/8 and 5/6) in colour with much mottling.

In Section 1, the base of the brickearth slopes markedly towards the Chalk cliff, as do all the higher units. This is probably the result of collapse of the upper beds into voids created by the solution of the 'coombe rock' near the Chalk cliff (Fig. 4), as described in bed 2.

This deposit has been previously termed the 'West Thurrock Brickearth', a name applied to clays/silts within what is now regarded as the Aveley Member in its outcrop to the west of Grays. Such deposits have

sometimes been confused with the older Grays-Thurrock/Little Thurrock brickearth, which forms part of the Corbets Tey Formation and which outcrops beneath central and eastern Grays (Bridgland & Harding 1993; Bridgland 1994).

Bed 4: Upper sand

This bed comprises fine or medium sands, interbedded with occasional gravel stringers and frequent silts, the latter being typically up to 2 cm thick and extending 1–1.5 m, but some for several metres. Essentially the sequence is horizontally bedded but much affected by secondary deformation. In Section 1 is seen slightly irregular bedding and faulting, whereas in Section 7 much of the deposit had been fluidised due to high pore water pressures, leading to loss of bedding and,

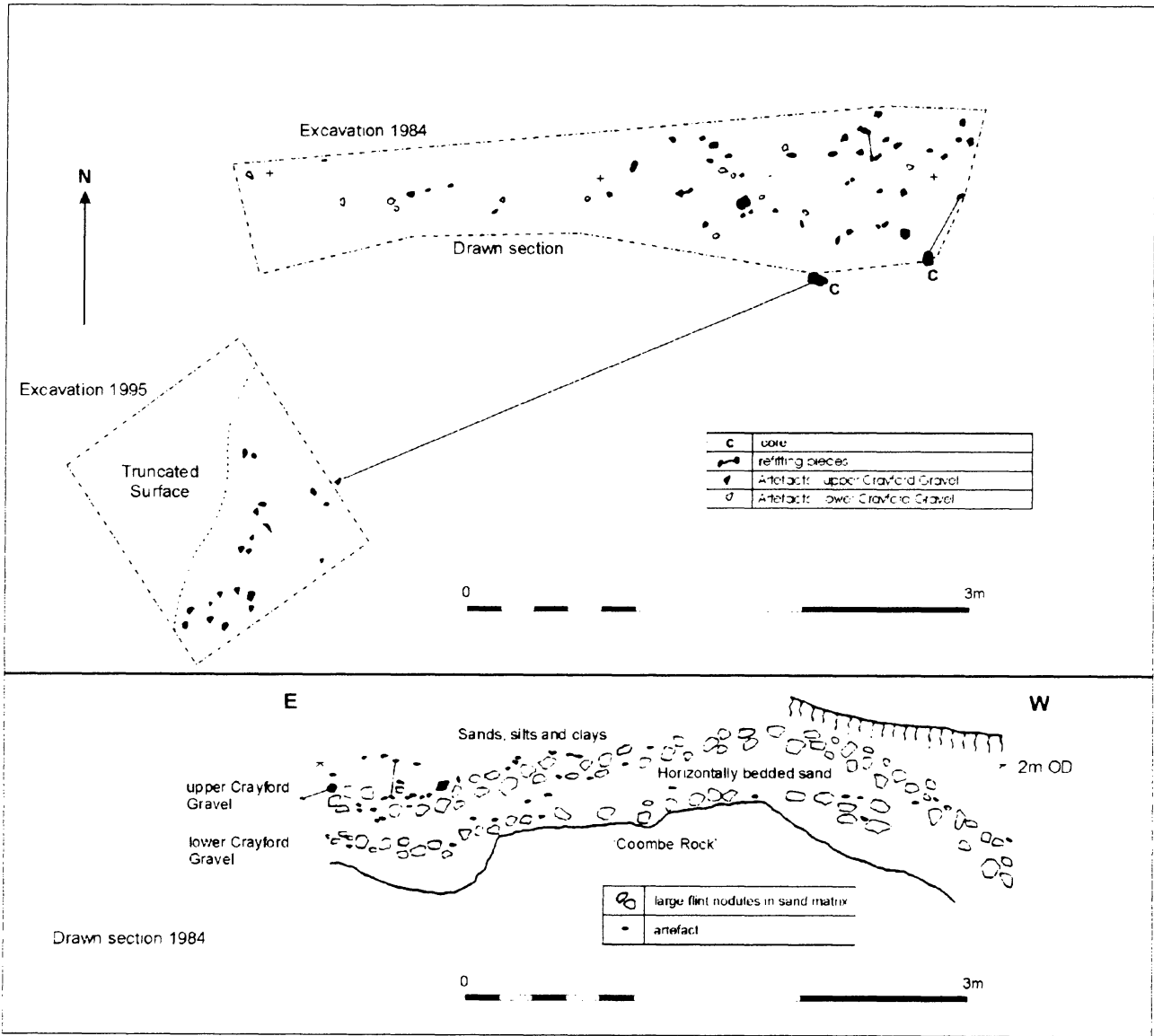


Fig. 5.

The archaeological strata at the base of section 1.

A: Plan of the 1984 and 1995 excavations, showing artefact plots. B: Reconstructed north-facing section (reversed), again showing artefact plots

in some cases, upwards ejection (water escape), though on a minor scale. The solution activity discussed for beds 2 and 3 was probably also a cause of the faulting observed in this bed.

Bed 5: West Thurrock Gravel

In the southern part of the tramway cutting an upper

gravel occurs, becoming increasingly dominant southwards (Fig. 2). In Section 2 the gravel, although clearly a bedded fluvial deposits, was highly disturbed by periglacial structures. In Section 7, 2.0 m of this gravel was seen, with poorly developed horizontal bedding and occasional sand lenses, 0.1 m thick. Gravel clast size ranged up to 0.15 m in diameter in the upper part of the bed. The attitude of pebble a-

axes is usually sub-horizontal, but a significant number are at higher angles, some nearly vertical, particularly towards the top, presumably the result of frost disturbance.

Bed 6: Unbedded gravelly, clayey sand

The sequence in Section 1 is capped by poorly-stratified and contorted clayey gravelly sand (bed 6), believed to be of solifluction origin. The emplacement and deformation of this uppermost deposit would have required a periglacial climate. The top of the underlying water-lain sequence has been involved in the deformation structures as well as being affected by temperate-climate pedogenic activity (see below), providing further evidence for a complex sequence of climatic fluctuations since the Levallois knapping site was occupied.

NEW LITHOSTRATIGRAPHICAL NOMENCLATURE

The lower gravel (bed 2) and upper gravel (bed 5) within the West Thurrock terrace sequence are regarded here as members of the Mucking Formation (*cf* Bridgland 1995). Classification of full Thames terrace sequences as members (*cf* Gibbard 1999) is considered untenable given their internal complexity, especially in the Lower Thames (*cf* Schreve *et al.* 2002). Three members are present at West Thurrock, representing a sequence of cold-climate (gravel), warm-climate (finer-grained deposits), and a return to cold-climate deposition. The warm-climate part of the sequence is well established as equivalent to interglacial sediments at other localities in the Lower Thames, including Ilford (Uphall Pit), Aveley, and Crayford (Bridgland 1994; 1995; *cf* Gibbard 1994). These have already been described under the name Aveley (Silts and Sands) Member (Gibbard 1994; 1999). The use of the names Mucking Lower and Mucking Upper Gravel conflicts with lithostratigraphical directives (Salvador 1994; Bowen 1999), which call for a unique geographical label for each unit. Gibbard (1994; Gibbard *et al.* 1988) has previously applied the name West Thurrock Gravel to the uppermost member, so this is retained here, although the Early Devensian age attributed by Gibbard to this deposit is not upheld (see below). This leaves only the lower gravel member requiring a name. Again, there is a name used for an equivalent gravel elsewhere in the Lower Thames that can be

adopted formally. This is the term Crayford Gravel, which Kennard (1944) applied to gravel underlying the interglacial 'brickearth' deposits in the Crayford–Erith district on the south side of the Thames. Since the Crayford interglacial deposits are correlated with those at Aveley and West Thurrock, the gravel underlying the last-mentioned is stratigraphically equivalent to the Crayford Gravel and can therefore be given that name.

SEDIMENTOLOGICAL AND PALAEOENVIRONMENTAL INVESTIGATIONS

Gravel composition

No new analyses have been undertaken since the site was previously described. As recorded by Bridgland and Harding (1994; 1995), the composition of both the Crayford and West Thurrock Gravels at this site is entirely consistent with deposition by the (Lower) Thames. It is 94–98% flint, with Greensand chert from the south and more exotic rocks from Midland and northern sources. These include quartz, quartzites, and Carboniferous and *Rhaxella* chert, mostly derived from outside the present Thames catchment (Bridgland 1988; 1994, table 4.2). Analyses have been restricted to material below the 32 mm sieve size; coarser fractions are even more dominated by flint, which makes up all the cobble-sized material in the coarse basal Crayford Gravel.

Sedimentology of the Aveley Member bedded sands and silts

The fluvial origin of the lower (Crayford) and upper (West Thurrock) gravels is clear, but the environment of deposition of the finer grained sediments requires further consideration, particularly since an estuarine origin has been claimed for parts of the sequence (Hollin 1977; Bridgland & Harding 1994). The only part of the succession in which fossils are available to assist with this question is the brickearth, but the aquatic fauna from here, limited though it is, fully freshwater in character. The lower and upper sands (beds 2 and 4) are entirely unfossiliferous, requiring that their interpretation be entirely from sedimentological evidence. The interbedded sands and silts of bed 4, as exposed in Section 1, were likened to the 'closely interlayered bedding ... of intertidal flats' (Bridgland & Harding 1994, 247).

The lower sands of bed 2 were deposited in a quiet water environment in which aggradation, rather than progradation, was dominant. The horizontal nature of the upper sands (bed 4) also indicates aggradation in a relatively quiet water environment. The frequent fluidisation of the sand suggests high pore water pressures but, given that the sands lie upon the clayey silt of bed 3, this would be expected. The horizontal nature of beds 2 and 4, adjacent to a steeply rising chalk cliff/bluff, suggests deposition in a quiet water environment, predominantly a sand flat, latterly replaced by short-lived mudflats (continuous clayey silt) or muddy areas (discontinuous clayey silt). The lack of cross-bedding and the paucity of ripples suggest a particularly quiet environment and the thickness of the deposit suggests the conditions persisted for a long time. The frequent medium grain size of the sand indicates that proximity of the (predominantly fine-grained) Thanet Sand cannot be argued to explain the presence and thickness of the deposit. Such a persistent environment of deposition is unlikely in the channel of a meandering or braided river but could be in keeping with the shore of a wide river or estuary at a time of rising sea-level. The location of the tramway cutting site in a minor embayment may help explain the quiet nature of the depositional environment. The juxtaposition of the sedimentary sequence to the Chalk cliff is significant. In open marine conditions, such a sedimentary sequence adjacent to a cliff would be vulnerable to destruction during storms. In a riparian situation, a river cliff persists only where powerful running water keeps the cliff base free of particulate or mass wasting debris. Neither of these scenarios applies in this case and the most likely explanation is that estuarine conditions pertained.

The appellation 'brickearth' has often been used for silt of aeolian origin, but the West Thurrock deposit is water-lain. Its fine-grained, horizontally bedded nature indicates deposition either in a mudflat or a quiet backwater. The brecciation of the much of the clayey silt (Section 7) suggests significant periods of drying out, some sufficiently prolonged to allow precipitation of the carbonate nodules. In keeping with this, the mottling suggests wetting, when the iron within the sediment was held in a reduced state giving grey/blue/black colours, and drying, when the contained iron oxidised to give brown colours. In contrast to this evidence of desiccation, the deformation of the overlying sand into the top of the silt indicates very high pore water pressures, sufficient

to make the sediments unstable. The frequency and intensity of the periods of desiccation would not be in keeping with the usual high water mark mudflat, but as the site lies in a palaeo-embayment, a backwater environment, possibly associated with a mudflat, might have persisted. Flocculation of clay and silt in a saline estuarine situation would help explain the unusual thickness of this fine-grained bed, up to 3 m.

Together, beds 0–6 indicate a progression from cold conditions with solifluction (bed 0), through periglacial braided river conditions (bed 1), to aggradation on a sand flat (bed 2) and then backwater or tidal flat conditions (beds 3–4). Thereafter, the sedimentary sequence reverts back to braided river and mass wasting conditions (beds 5–6).

Mollusca

Four samples (1–4, Table 1) were collected from the clayey silt (bed 3) in Section 5. All were washed through a 500 µm mesh and sorted dry under a x10–60 microscope. The shell content was abundant but because of partial decalcification, most molluscan material present was of the calcite opercula of *Bithynia tentaculata*, rather than aragonite shells. Consequently identification of the fragments of shell was difficult and the counts in Table 1 must be regarded as minimum numbers of species and individuals.

Taxonomic nomenclature follows Kerney (1999) for current British species and Turner *et al.* (1998) for species now extinct in Britain. A total of 28 taxa is now recorded from the West Thurrock deposits. The current samples yielded 20 taxa (Table 1), with the additional eight coming from the earlier records by Woodward (1890), Carreck (1972), Hollin (1977), and Preece (in Schreve 1997). The majority of this assemblage is representative of aquatic habitats. Most numerous are the gastropods *Valvata piscinalis* and *Bithynia tentaculata*, species of slow-flowing rivers with some macrophytic vegetation and water depths of at least 2–5 m. Such conditions would also be optimal for the river group of small bivalves (*Pisidium amnicum*, *P. henslowanum*, and *P. moitessierianum*), which together are the most numerous in the samples. A moderate-sized river would also be the most likely habitat for *Corbicula fluminalis*, the other numerous small bivalve in the assemblage. The remaining species are restricted in numbers. *Belgrandia marginata* is represented only by two apertural rings rather than whole shells, and the Planorbidae were largely identified by fragments of ribbed or ornamented shell

2. D. Schreve et al. A LEVALLOIS KNAPPING SITE AT WEST THURROCK, LOWER THAMES, UK

(*Planorbis planorbis* and *Gyraulus albus*) rather than anything approaching complete shells. None of these taxa would be at variance with the suggestion that the sediments were deposited in a river of moderate size, such as the Thames.

Land molluscs are exceptionally sparse, due probably to decalcification, although the low numbers of the resistant calcite plates of Limacid slugs suggests that quantities of shells from terrestrial environments in the sediments may never have been large.

Although the number of taxa is smaller than would

be expected from a temperate-climate assemblage (Keen 1990), individual species present are strongly indicative of fully interglacial conditions. Species such as *B. marginata*, *C. fluminalis*, *P. henslowanum*, and *P. moitessierianum* have only been found in temperate contexts in British fluvial deposits. No species indicative of a cold climate have been found in the deposits. The assemblage is fully freshwater, although many of these taxa (*C. fluminalis*, for example) can be found in estuarine environments, having been carried downstream.

TABLE 1. MOLLUSCA FROM THE LION PIT TRAMWAY CUTTING, WEST THURROCK

Sample	1	2	3	4	5	6
<i>Valvata piscinalis</i> (Müller, 1774)	19	25	23	11	*	-
<i>Belgrandia marginata</i> (Michaud, 1831)	-	1	-	1	-	-
<i>Bithynia tentaculata</i> (Linné, 1758)	22	25	17	4	*	-
opercula	1919	3090	779	487	-	-
<i>B. troscheli</i> (Paasch, 1842) opercula	-	-	2	-	-	-
<i>Lymnaea truncatula</i> (Müller, 1774)	-	-	-	-	-	*
<i>L. palustris</i> (Müller, 1774)	-	-	-	-	-	*
<i>L. peregra</i> (Müller, 1774)	1	-	3	-	*	-
<i>Lymnaea</i> spp.	3	4	-	-	-	-
<i>Planorbis planorbis</i> (Linné, 1758)	1	-	-	-	-	-
<i>Anisus leucostoma</i> (Millet, 1813) §	-	-	-	-	-	*
<i>Gyraulus albus</i> (Müller, 1774)	1	-	-	-	*	-
<i>Hippeutis complanatus</i> (Linné, 1758)	-	-	-	-	-	*
<i>Planorbarius corneus</i> (Linné, 1758)	-	-	-	-	-	*
<i>Planorbidae</i> undet.	2	1	1	-	*	-
<i>Ancylus fluviatilis</i> Müller, 1774	1	-	1	-	*	-
<i>Anodonta</i> spp.	-	-	-	-	-	*
<i>Sphaerium</i> spp.	-	-	-	-	*	*
<i>Corbicula fluminalis</i> (Müller, 1774)	1	2	2	1	-	-
<i>Pisidium amnicum</i> (Müller, 1774)	2	2	4	1	*	-
<i>P. clessini</i> Neumayr, 1875	-	-	-	1	-	-
<i>P. casertanum</i> (Poli, 1791)	-	-	-	-	*	-
<i>P. subtruncatum</i> Malm, 1855	1	1	2	-	*	-
<i>P. henslowanum</i> (Sheppard, 1823)	2	2	2	-	-	-
<i>P. nitidum</i> Jenyns, 1832	-	-	2	1	-	-
<i>P. moitessierianum</i> Paladilhe, 1866	3	4	3	-	*	-
<i>Pisidium</i> spp.	6	10	6	3	-	-
<i>Succineidae</i> undet.	1	1	1	-	-	-
<i>Pupilla muscorum</i> (Linné, 1758)	-	-	-	-	-	*
<i>Limax</i> spp.	1	3	1	-	-	-
<i>Helicella itala</i> (Linné, 1758)	-	-	-	-	-	*
<i>Trichia</i> spp.	-	1	-	-	-	-
Total (24 species, 20 freshwater, 4 land)	66	83	68	21	-	-

1: Section 5, sample 3; 2: Section 5, sample 4; 3: Section 5, sample 6; 4: Sample collected 8-7-00 (Geologists' Association meeting); 5: Preece list from Schreve (1997); 6: List of earlier authors (Woodward 1890; Carreck 1972; Hollin 1977)

§ Recorded as *Planorbis leucostoma*

Vertebrates

Eleven mammalian taxa from the Aveley Member at West Thurrock were identified by Schreve (1997), based upon material in Abbott's collection, material collected by Hinton and other unidentified collectors between c. 1900 and 1931, and new samples taken in 1995 from Lion cutting Section 5 (Table 2). Bulk samples were washed through a 500µm mesh and sorted dry under a low-power binocular microscope.

Abbott collected his material from over 30 ft (9 m) of 'light brownish-grey sand, current-bedded in lower part, passing into clay or silt' (his bed c), which overlay sandy gravel at the base of the cliff, and from a higher 'Fine sand without current-bedding, becoming rather marly upward', up to 35 ft (10 m), his bed c' (Abbott, 1890). These two beds were apparently separated by a clay lenticle up to 1 m thick (bed d), which thinned and disappeared over a distance of 600 yards (550 m). Above bed c', the sequence passed into up to 5 ft (1.5 m) of impersistent calcareous clay. It therefore seems likely that at least some of the bones came from the probable equivalent of bed 2 (lower sand). Others came from a thick sand bed between two silty clays, one or other (or both) of which may be the equivalent of bed 3. Unfortunately, there is nothing marked on the specimens that might permit their separation according to stratigraphic unit. Abbott (1890) reported finding a partial elephant skeleton in bed c', at the top of which he also noted a layer of crushed ivory several metres long and up to 0.25 m thick.

Table 2 includes two species, horse (*Equus ferus*) and Merck's rhinoceros (*Stephanorhinus kirchbergensis*), which were recorded by Abbott (1890) but were not listed by Carreck (1972; 1976), as well as two previously-unpublished species from the Abbott Collection: red fox (*Vulpes vulpes*) and brown bear (*Ursus* cf. *arctos*). In addition, a new small vertebrate assemblage was recovered from bulk samples of the clayey silt (bed 3), comprising indeterminate mouse (*Apodemus* sp.), eel (*Anguilla anguilla*), three-spined stickleback (*Gasterosteus aculeatus*), roach (*Rutilus rutilus*), tench (*Tinca tinca*), rudd (*Scardinius erythrophthalmus*), and perch (*Perca fluviatilis*). No specimens of hippopotamus, *Hippopotamus amphibius* Linné, 1758, have been found in the collections and it has been concluded that Abbott's record was most probably based upon a misidentification (Currant in Bridgland 1994). Equally, a record of giant deer, *Megaloceros giganteus*

(Blumenbach, 1803) listed by Abbott (1890) could not be verified. In the clayey silt, the paucity of small mammal remains (two incisors and a broken murid molar) in comparison to fish is noticeable, suggesting that the sampling point may be located towards the middle of the contemporary channel. This would also account for the low numbers of land molluscs (see above). The fish remains are generally well preserved and the presence of fragile elements, such as perch scales, attests to a relatively gentle depositional regime and a subsequent lack of disturbance. Preservation of the large mammal material is generally good with most material mid-brown in colour with black and/or orange mottling.

There is evidence of modification of a first phalanx of a large bovid (cf. *Bos primigenius*) from the Abbott collection, which shows the typical gnawmarks of a medium-sized carnivore on its proximal articular surface. More intriguing is the presence of several series of cutmarks on the left acetabular shaft of the ischium of a narrow-nosed rhinoceros (*Stephanorhinus hemitoechus*; Figs 6 & 7). The marks have been produced by sharp stone and are concentrated around the margin of the obturator foramen, an area where butchery and detachment of muscle blocks would leave characteristic traces. The absence of marks or scratches on other bones in the collection, the particular location of the cutmarks on that part of the pelvis, and the fine-grained nature of the deposits from which the bones have come combine to support the theory that the marks were not naturally created. It is therefore tentatively suggested that this rhinoceros pelvis may have been deliberately butchered by early hominins. Rhinoceros butchery with similar cutmarks around the obturator foramen is known from the early Middle Pleistocene site of Boxgrove, West Sussex (Roberts & Parfitt 1999), and several examples of horse butchery, also with cutmarks around that part of the pelvis, are known from the Lateglacial deposits in Gough's Cave, Somerset (Parkin *et al.* 1986).

The presence of *Apodemus* sp., *U.* cf. *arctos*, *P. antiquus*, and *S. kirchbergensis* implies the presence of nearby deciduous or mixed woodland, although by far the most important local habitat appears to be open grassland, presumably adjacent to the river. This is indicated by the presence of large grazing or semi-grazing herbivores, such as mammoth, narrow-nosed rhinoceros, red deer, horse, aurochs, and bison, which together make up nearly 85% of the assemblage.

2. D. Schreve et al. A LEVALLOIS KNAPPING SITE AT WEST THURROCK, LOWER THAMES, UK

TABLE 2. VERTEBRATES FROM THE LION PIT TRAMWAY CUTTING, WEST THURROCK.

Taxon	1	2	3	4	5	6	MNI
PISCES							
Anguillidae							
<i>Anguilla anguilla</i> Linné, 1758, eel	+	-	-	-	-	-	
Esocidae							
<i>Esox lucius</i> Linné, 1758, pike	+	+	-	-	+	-	
Gasterosteidae							
<i>Gasterosteus aculeatus</i> Linné, 1758, three-spined stickleback	+	+	-	+	-	-	
Cyprinidae							
<i>Rutilus rutilus</i> (Linné, 1758), roach	+	+	+	+	-	-	
<i>Tinca tinca</i> (Linné, 1758), tench	-	+	+	+	-	-	
<i>Scardinius erythrophthalmus</i> (Linné, 1758), rudd	+	+	-	-	-	-	
Cyprinidae undet., undetermined carp family	-	+	+	-	-	-	
Percidae							
<i>Perca fluviatilis</i> Linné, 1758, perch	+	-	+	+	+	-	
Undetermined fish	+	-	+	+	+	-	
MAMMALIA							
Cricetidae							
Cricetidae sp., indeterminate cricetid	-	-	1	-	-	-	1
Muridae							
<i>Apodemus sylvaticus</i> (Linné, 1758), wood mouse	1	-	1	-	-	-	1
Canidae							
<i>Vulpes vulpes</i> Linné, 1758, red fox	-	-	-	-	-	1	1
Ursidae							
<i>Ursus</i> cf. <i>arctos</i> Linné, 1758, brown bear	-	-	-	-	-	1	1
Elephantidae							
<i>Palaeoloxodon antiquus</i> (Falconer and Cautley, 1845), straight-tusked elephant	-	-	-	-	-	1	1
<i>Mammuthus trogontherii</i> (Pohlg, 1888) Steppe Mammoth	-	-	-	-	-	24	2
<i>Elephantidae</i> sp., undetermined elephant	-	-	-	-	-	3	1
Equidae							
<i>Equus ferus</i> Boddaert, 1785, horse	-	-	-	-	-	1	1
Rhinocerotidae							
<i>Stephanorhinus hemitoechus</i> (Falconer, 1868), narrow-nosed rhinoceros	-	-	-	-	-	6	2
<i>Stephanorhinus kirchbergensis</i> (Jäger, 1839), Merck's rhinoceros	-	-	-	-	-	4	2
Cervidae							
<i>Cervus elaphus</i> Linné, 1758, red deer	-	-	-	-	-	2	1
Bovidae							
cf. <i>Bos primigenius</i> Bojanus 1827, aurochs	-	-	-	-	-	16	1
cf. <i>Bison priscus</i> Bojanus, 1827, bison	-	-	-	-	-	1	1
Bovidae sp., undermined large bovid (<i>Bos</i> or <i>Bison</i>)	-	-	-	-	-	10	1

1 = 1995 Section 5 DCS Sample 1; 2 = 1995 Section 5 DCS Sample 2; 3 = 1995 Section 5 DHK Sample 3; 4 = 1995 Section 5 DHK Sample 4; 5 = Sample collected 8-7-00 (Geologists' Association meeting); 6 = Specimens from Abbott Collection

(+ denotes presence of fish only; MNI = Minimum Number of Individuals; figures given for mammalian material only)

Interglacial conditions are implied by the two species of rhinoceros, straight-tusked elephant, and aurochs, since these taxa are restricted to temperate occurrences during the Pleistocene. The fish remains corroborate the prevalence of warm climatic conditions, in particular the presence of tench, which

requires mean summer water temperatures not lower than 18° C for spawning (Wheeler 1969). The fish assemblage is characteristic of stagnant or very slowly flowing poorly-oxygenated water with an abundance of aquatic vegetation, typical of ponds, river backwaters, or the lower reaches of large rivers. The

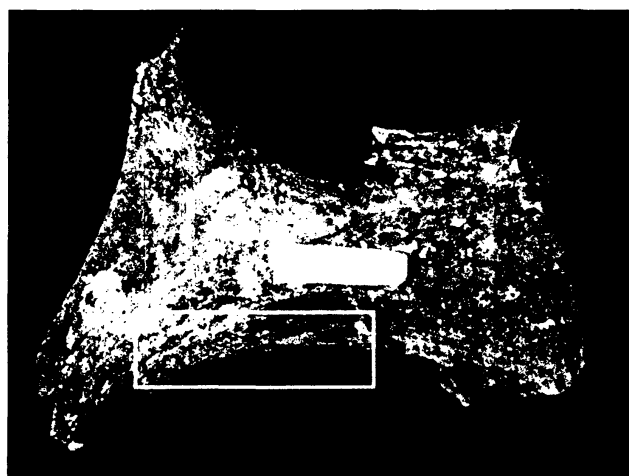


Fig. 6.
Fragment of ischium of *Stephanorhinus hemitoechus*
with putative cutmarks. Box shows area of cuts
(length of box: 80 mm)

three-spined stickleback and tench are both tolerant of estuarine conditions (Wheeler 1969), whereas the catadromous eel requires a link to the sea, at least seasonally.

Pollen

Several samples of brickearth from the tramway cutting were sampled for pollen by Hollin (1977). The results demonstrated that pollen abundances are very low, the only countable sample coming from the east side of the cutting, approximately 0.3 m above the base of the brickearth. The restricted pollen assemblage was dominated by *Alnus* and Filicales, with *Carpinus*, *Corylus*, and lower frequencies of *Pinus*, *Quercus*, *Tilia*, and *Fraxinus* (Hollin 1977). Similar pollen spectra, considered to represent two pollen assemblage biozones, were reported by Gibbard (1994) from the 1983/4 temporary exposure in a road cutting 0.9 km west of the tramway cutting:

75–90 cm *Alnus-Pinus-herb* p.a.b. (Ip IV)
0–75 cm *Alnus-Carpinus* p.a.b. (Ip III)

The spectra from the lower p.a.b. were dominated by pollen of thermophilous woodland taxa (*Alnus* and *Carpinus*) and arboreal pollen represented 90% of the total assemblage, suggesting that grassland was not extensive near the site. The vegetation adjacent to the

river is reconstructed as alder fen carr, with the development of hornbeam forest occurring on nearby dry calcareous soils (Gibbard 1994). The upper p.a.b. shows the decline of *Carpinus* and *Alnus* and their replacement by *Pinus* and *Betula*, with low frequencies of *Picea*, *Quercus*, and *Corylus*. Pollen of grasses, sedges, and herbs increased during this zone, suggesting the spread of local grassland. Pollen counts from the tramway cutting itself, also undertaken by Gibbard (1994) and R.G. West (in Gibbard 1994), appear to represent only the lower p.a.b. The lower p.a.b. was attributed to substage III and the upper p.a.b. to substage IV of the Ipswichian Interglacial by Gibbard (1994), in agreement with the interpretations of Hollin (1977).

Pedostratigraphical evidence

A (non-buried) palaeosol was sampled near the top of Section 1 (Clayton 1996; Fig. 4). There is evidence for a complex soil, with a truncated older soil overlain by renewed deposition and then reactivated by later pedogenesis. This earlier activity is represented in the 2BCt horizon developed in the sandy upper part of bed 4 (Fig. 4). Four further soil horizons (Eb1–Bt2 horizons) are represented within the poorly stratified sand and gravel of bed 6. The reddish colours (7.5 YR to 5 YR hues) border on those considered typical of palaeo-argillic soils (Avery 1980). These hues, the occurrence of vertically oriented stones, and a clay maximum in the Bt2 horizon suggest that this might be a palaeo-argillic soil formed over at least one

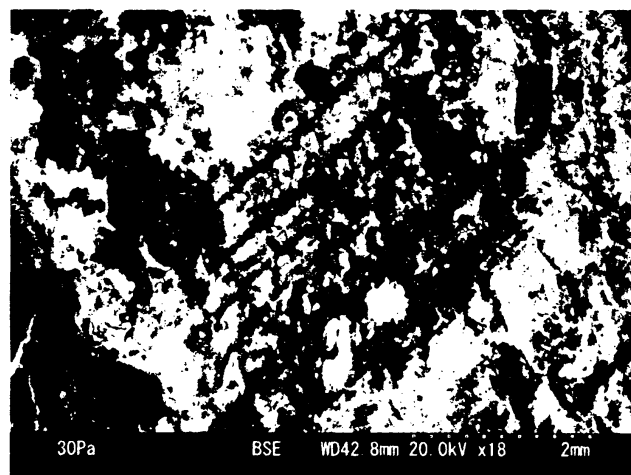


Fig. 7.
SEM photograph of cutmark detail

interglacial–glacial cycle prior to the Holocene (Avery 1985). Two distinct phases of clay illuviation were identified, with the earlier of these represented by coatings only found in the 2BCt horizon developed in bed 4; such coatings are absent in the sands and gravels, despite the red colouration of the latter. The 2BCt horizon developed in bed 4 is thus interpreted as a truncated brown earth containing relict illuvial features, probably dating from an earlier temperate (interglacial or interstadial) episode. The coatings of this first illuvial phase are predominantly fragmented and occur in bands. They are associated with duplex textural lamellae features (Kemp 1987), formed in response to repeated ice segregation and melting under cold climatic conditions. The overlying sand and gravel (bed 6) parent material, possibly mixed with loess, was probably emplaced by solifluction during the same cold stage. A further phase of clay translocation took place during the Holocene, with resultant illuvial features forming in both the Bt and 2BCt horizons.

The upper part of Section 1 constitutes a welded palaeosol comprising a Holocene profile developed in solifluction material (bed 6) that extends into an underlying truncated lower horizon of an interglacial brown earth soil developed in the top of bed 4. It is not clear whether the earlier pedogenesis took place during the waning of the interglacial represented by estuarine deposition (considered here to be MIS 7) or during a later temperate episode.

Amino acid geochronology

Amino acid racemisation (AAR) studies have proved to be a helpful if controversial means of obtaining age indications for parts of the Thames sequence (Miller *et al.* 1979; Bowen *et al.* 1989; 1995). Previous studies have shown good agreement with mammalian and molluscan biostratigraphy in determining between genuine Last Interglacial sediments and deposits laid down during the penultimate (MIS 7) interglacial. Most of the problems and controversy have stemmed from results from pre-MIS 7 contexts (see, however, Gibbard 1994; McCarroll 2002). Although it was not included amongst the sites from which data were published in the 1970s or '80s, Hollin (1996) reported amino acid ratios from West Thurrock, from opercula of *Bithynia tentaculata*, of 0.18 ± 0.01 ($n=4$) AAL-4108. These ratios were compatible with those from other localities attributed to MIS 7, although operculum analyses were not widely undertaken in the early work of this sort. Subsequently *Bithynia* opercula

have provided an impressive database of AAR results based on a modified application at the University of York, including new analyses from the Lion Pit cutting.

AAR analyses were undertaken at York on five *B. tentaculata* opercula from Section 5, Sample 6 (NEaar 1575–1579). All samples were prepared using the procedures of Penkman (2005). In brief, each operculum was powdered and bleached for 48 hours with 12% NaOCl. Two subsamples were taken: one fraction was directly demineralised and the free amino acids analysed (referred to as the 'Free' fraction, F), and the second was treated with 7 M HCl at 110°C for 24 hours (referred to as the 'Hydrolysed' fraction, H*) to release the peptide-bound amino acids. Samples were then dried by centrifugal evaporator and rehydrated for HPLC analysis with 0.01 mM L-homo-Arginine as an internal standard.

The amino acid compositions of the samples were analysed in duplicate by reverse-phase HPLC using fluorescence detection following the method of Kaufman and Manley (1998). 2 µl of sample is injected and mixed online with 2.2 µl of derivitising reagent (260 mM *N*-Iso-L-butyryl L-cysteine (IBLC), 170 mM *o*-phthaldialdehyde (OPA) in 1 M potassium borate buffer, adjusted to pH 10.4 with potassium hydroxide pellets). The amino acids are separated on a C₁₈ HyperSil BDS column (5 mm * 250 mm) at 25°C using a gradient elution of 3 solvents: sodium acetate buffer (solvent A; 23 mM sodium acetate tri-hydrate, 1.5 mM sodium azide, 1.3 µM EDTA, adjusted to pH 6.00 ± 0.01 with 10% acetic acid and sodium hydroxide), methanol (solvent C), and acetonitrile (solvent D). The L and D isomers of 12 amino acids were routinely analysed. During preparative hydrolysis both asparagine and glutamine undergo rapid irreversible deamination to aspartic acid and glutamic acid respectively (Hill 1965). It is therefore not possible to distinguish between the acidic amino acids and their derivatives and they are reported together as Asx and Glx. The D/L ratios of glutamic acid/glutamine, aspartic acid/asparagine, serine, alanine, and valine (D/L Asx, Glx, Ser, Ala, Val) are then combined to provide an overall estimate of protein decomposition using the degradation model kinetic (current version DMK v2.0Glx).

On the basis of the relative D/L ratios and concentrations (Table 3) the amino acid data obtained from the new method, when compared with unpublished values from sites attributed to MIS 17–5a, are consistent with an MIS 7 assignment (Penkman

TABLE 3: DATA USED TO DERIVE DEGRADATION MODEL KINETIC (DMK) VALUES. ERROR TERMS ARE ONE STANDARD DEVIATION ON THE DUPLICATE ANALYSES.

NEaar no.	Asx D/L	Glx D/L	Ser D/L	Ala D/L	Val D/L	[Ser]/[Ala]
1575bF	0.711 ± 0.000	0.283 ± 0.002	0.986 ± 0.003	0.361 ± 0.003	0.198 ± 0.001	0.451 ± 0.000
1575bH*	0.614 ± 0.005	0.195 ± 0.003	0.734 ± 0.007	0.304 ± 0.008	0.149 ± 0.000	0.417 ± 0.002
1576bF	0.718 ± 0.002	0.303 ± 0.001	0.976 ± 0.007	0.351 ± 0.004	0.199 ± 0.013	0.483 ± 0.005
1576bH*	0.629 ± 0.002	0.220 ± 0.003	0.769 ± 0.000	0.302 ± 0.000	0.153 ± 0.001	0.460 ± 0.000
1577bF	0.710 ± 0.001	0.303 ± 0.001	0.988 ± 0.010	0.374 ± 0.005	0.204 ± 0.001	0.516 ± 0.005
1577bH*	0.620 ± 0.000	0.226 ± 0.000	0.768 ± 0.002	0.323 ± 0.013	0.171 ± 0.001	0.505 ± 0.007
1578bF	0.707 ± 0.003	0.289 ± 0.005	0.992 ± 0.011	0.366 ± 0.001	0.201 ± 0.002	0.488 ± 0.000
1578bH*	0.609 ± 0.007	0.197 ± 0.002	0.721 ± 0.006	0.308 ± 0.001	0.160 ± 0.000	0.430 ± 0.004
1579bF	0.704 ± 0.020	0.291 ± 0.002	0.978 ± 0.003	0.360 ± 0.001	0.202 ± 0.003	0.418 ± 0.001
1579bH*	0.628 ± 0.002	0.200 ± 0.001	0.712 ± 0.001	0.292 ± 0.001	0.199 ± 0.009	0.385 ± 0.000

2005). The *Bithynia tentaculata* opercula have amino acid ratios that are higher than those of the same species from Ipswichian sites (Trafalgar Square, East Mersea Restaurant Site, Shropham, Coston), correlated with MIS 5e. The ratios are also lower than those sites attributed to MIS 9 (Cudmore Grove, Hackney, Purfleet, and Grays). The opercula amino acid data cluster with that obtained from sites correlated with MIS 7, such as Aveley. Although the data obtained by these new processes are not directly comparable with ratios obtained during the earlier analyses, they point to the same interpretation for the interglacial sediments at West Thurrock, namely deposition during MIS 7.

ARCHAEOLOGICAL INVESTIGATIONS: THE PALAEOLITHIC 'FLOOR'

With the exception of isolated finds of small flakes within the higher sandy and gravelly strata, the anthropogenic origin of which is equivocal, the archaeological record at West Thurrock is restricted to the lower gravel (Crayford Member). The 'Levallois floor' occurs, exactly as described by Dibley and Kennard (1916), in this gravel, at the foot of a Chalk cliff and beneath a thick sequence of Quaternary sediments.

Method of investigation

Controlled excavations were undertaken in two small trenches opened in 1984 and 1995. The area of the Levallois floor available for examination was restricted by the considerable thickness of overlying Quaternary deposits and the base of the cutting was accordingly cut back in 1984 by approximately 1 m at the eastern end to expose a narrow wedge-shaped area

c. 4 m long. Limited amounts of *in situ* Crayford Gravel were removed on these occasions and artefacts found within it were plotted in three dimensions and planned at a scale of 1:10 (Fig. 5). Wherever possible, orientation, angle, and direction of rest were noted. The excavation of 1995 exposed a small area approximately 1.2 m by 1.4 m located south-east of the 1984 excavation (Fig. 5).

The Palaeolithic assemblage

The small-scale excavations of 1984 and 1995 produced a total of 144 unequivocal artefacts (Table 4), hinting at the potential richness of this hard-to-access site. All were recovered from the Crayford Gravel. Sixty-three artefacts were excavated from the upper division of the gravel (here referred to as the upper Crayford Gravel), in association with a layer of large flint nodules, whereas 14 apparently came from within or below the layer of horizontally bedded sand that separates the upper from the lower division of the gravel (lower Crayford Gravel). The remaining artefacts were apparently not recovered during the controlled excavation, since they bear no stratigraphic data, and therefore cannot be plotted or assigned to a specific part of the Crayford Gravel, although it can be stated with certainty that they originated from within it. Most of these were recovered in cleaning up the machine-dug trenches prior to the controlled excavation of *in situ* deposit. Others were added to the assemblage following their procurement from the sections during the 1984 and 1995 field visits.

In addition, the excavations yielded a large quantity of naturally flaked pieces produced *in situ* in the gravel by sub-surface pressure flaking, exactly as observed and described by Warren in the bull-head

TABLE 4: INVENTORY OF ARTEFACTS

Artefact	1984 Excavations	1995 Excavations	BM Warren Collection	Total
Cores	4	0	7	11
Levallois flakes	6	3	14	23
Flake tools	2	0	0	2
Debitage >20mm	99	18	54	171
Debitage <20mm	10	2	8	20
Handaxes	0	0	1	1
Total	121	23	84	228

bed at nearby Grays (Warren 1923b), or by gravel collision during fluvial transport. The natural flakes could be distinguished from genuine artefacts on the basis of being totally unpatinated, in mint condition, and having a matt surface sheen. All such pieces have been disregarded.

The distribution of the artefacts (Fig. 5) probably reflects a combination of human discard patterns and fluvial disturbance. The flakes generally showed no preferential orientation or aspect, although one flake from 1984 was recorded on edge and one from 1995 on end. The distribution of material from the 1984 excavation in the upper Crayford Gravel (Fig. 5) shows a greater density of material in the eastern end of the trench, with significantly fewer finds coming from the western end. The 1995 trench, however, showed that denser scatters also exist to the south-west. This pattern may be a true reflection of activity near the base of the cliff or it may relate to the truncation of the archaeological horizon towards the north-west or to fluvial re-arrangement. When the material from the upper Crayford Gravel and lower Crayford Gravel is combined, however, the difference is slightly less marked and it is clear that artefacts from the two horizons are never found in vertical superposition in any one place. Indeed, finds from the lower Crayford Gravel generally correspond to gaps between the nodules in the upper Crayford Gravel and tend to lie above or on the lower nodule layer, rather than being distributed within it, as is the case for the upper find horizon. Conjoinable artefacts in the upper Crayford Gravel show that vertical displacement of up to 0.2 m has occurred in this bed, which is greater than the distance between objects in the upper and lower Gravel units. These data suggest that artefacts from the upper Crayford Gravel may have been

vertically displaced, working down through the bedded sands and coming to rest on large obstacles beneath (*cf.* Villa 1982), although the lack of refits between the two find horizons makes this impossible to test further at present.

Thus it can be concluded that a single vertically displaced assemblage is probably present. The most parsimonious interpretation of the material would be to regard it as broadly contemporaneous within a single bed, although, as the refitting groups show, it is often possible to demonstrate much more precise contemporaneity. The following analysis therefore treats all the finds from the excavation and the unplotted pieces as part of a single assemblage discarded over a relatively short space of time.

The present analysis follows Boëda's approach to the study of Levallois technology (Boëda 1986; 1995; Boëda *et al.* 1990), which adopts a technological rather than typological view, defining six technical and geometric principles that underwrite all Levallois production (the Levallois concept; see Fig. 8 for details). To qualify as Levallois all six criteria must be met, but the manner in which the criteria are executed and the initialisation phase may vary, thereby producing the range of variation now recognised within the term Levallois. For example, Levallois may vary in the mode of preparation, which may be centripetal, unipolar, or bipolar. The same patterns are evident in the mode of exploitation, with a further distinction being made between lineal (or preferential) exploitation, where only a single final flake is removed from each prepared flaking surface, or recurrent exploitation, where several flakes are removed from each prepared flaking surface. This and other recent work (eg Van Peer 1992; Dibble & Bar-Yosef 1995) has also demonstrated that the Levallois

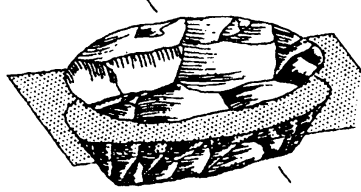
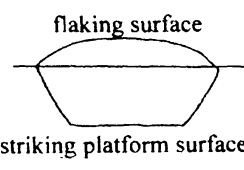
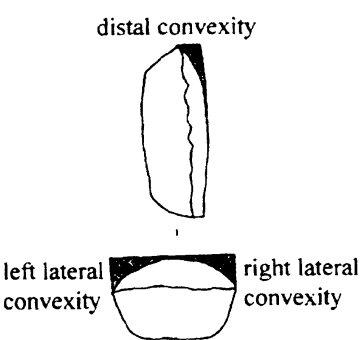

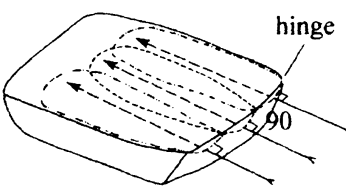

<p>Criterion 1: The volume of the core is conceived as two surfaces separated by a plane of intersection</p>	
<p>Criterion 2: The two surfaces are hierarchically related and non-interchangeable, one being a dedicated surface of striking platforms, the other a dedicated flaking surface</p>	
<p>Criterion 3: The flaking surface is configured in a fashion that predetermines the morphology of the products. This predetermination is controlled by the management of lateral and distal convexities</p>	
<p>Criterion 4: The fracture plane for the removal of predetermined blanks is parallel to plane of intersection</p>	
<p>Criterion 5: The line created by the intersection of the striking platform surface and the flaking surface (the hinge) is perpendicular to the flaking axis of the predetermined blanks.</p>	
<p>Criterion 6: Hard-hammer percussion</p>	

Fig. 8.
Boëda's Levallois concept

flaking surface was frequently rejuvenated to facilitate new production episodes, meaning that Levallois is not the profligate technique it was once believed to be and that the methods used may have changed through the productive life of a core.

Raw materials

Most or all of the artefacts from the Tramway Cutting have been produced using flint from the Crayford Gravel. This consists of large, irregular flint nodules eroded from the underlying Chalk, many of which contain thermal fractures, as well as some bullhead flint. The flint is naturally fine-grained and black, although with some coarser grey inclusions or pockets of chalcedony or grey chert. It has a mixture of very fresh and heavily weathered cortex and is generally of good knapping quality.

Condition

Ninety per cent of the artefacts from the Tramway Cutting are in fresh, sharp condition with no abrasion to the edges or arêtes. The remaining 10% are only slightly rolled. This supports other observations that the assemblage has seen only limited fluvial re-arrangement. However, all of the artefacts show edge damage, probably caused by post-depositional trampling and/or crushing within the sediment body, although 83% was considered to be minor and only 17% moderate to severe. None of the artefacts shows any staining but 96% show slight or moderate patination.

Cores

Four cores were recovered from the upper Crayford Gravel, three of which are clearly Levallois. The other was broken in a knapping accident and it is therefore more difficult to determine the method of exploitation.

Artefact LTC84/95 (Fig. 9.1) is a centripetally prepared lineal Levallois core (classic tortoise core), showing radial preparation to both the flaking surface and the striking platform surface, the latter retaining c. 50% cortex and/or naturally fractured surfaces. The final removal from this core was a large preferential flake, roughly rectilinear in form and measuring 116 x 77 mm.

LTC84/96 is a unipolar recurrent Levallois core (Fig. 9.2). The flaking surface has been prepared by a series of converging laminar removals mostly

organised from a single direction. The striking platform surface is 80% cortical, although clearly shows extensive platform preparation at the proximal end and two removals from the distal end to facilitate the required convexity (these are conjoinable: LTC84/194 and LTC101). The final phase of exploitation was a recurrent episode from a single direction, producing two large rectilinear flakes (largest 131 mm) and a point from the same flaking surface. The point (LTC84/123), which was the first removal in the sequence, is present in the collection and refits to the core. The other complete Levallois core (LTC184/Upper floor unplotted) has also been prepared unidirectionally and shows two recurrent final removals, the last of which shows a dramatic distal hinge fracture.

The broken core (LTC84/97) was also probably once unipolar Levallois but, following a knapping accident, at least two large flakes were then taken from the broken surface. This core has two refitting preparatory flakes from the edges of the flaking surface and another from the striking platform surface (Fig. 9.3).

The excavated cores therefore show the presence of two different Levallois operational schema at the Lion Pit tramway cutting. The Warren collection (see below) shows two more.

Levallois end-products

The excavated sample contains ten Levallois end-products (Figs 10.1 & 10.2) ranging in size from 70 mm to 105 mm, including one point and an *éclat débordant* (produced through the removal of the core edge to rejuvenate and maintain lateral convexity). As with the cores, the flakes also show evidence of both centripetal and unidirectional preparation, with a bias towards unipolar recurrent exploitation. Of the seven pieces that have a butt, six are faceted. Apart from one broken point, none of the final products detached from the cores has been identified in the collection. They may have been removed by human agency, a statement made more plausible by the fact that seven out of nine products left at the site were broken during manufacture and were presumably rejected for this reason.

Debitage

The excavation yielded a total of 117 flakes >20 mm and 12 <20 mm, with a mean length of 49.8±21.8 and a range of 15–120 mm (see Table 5 for summary of

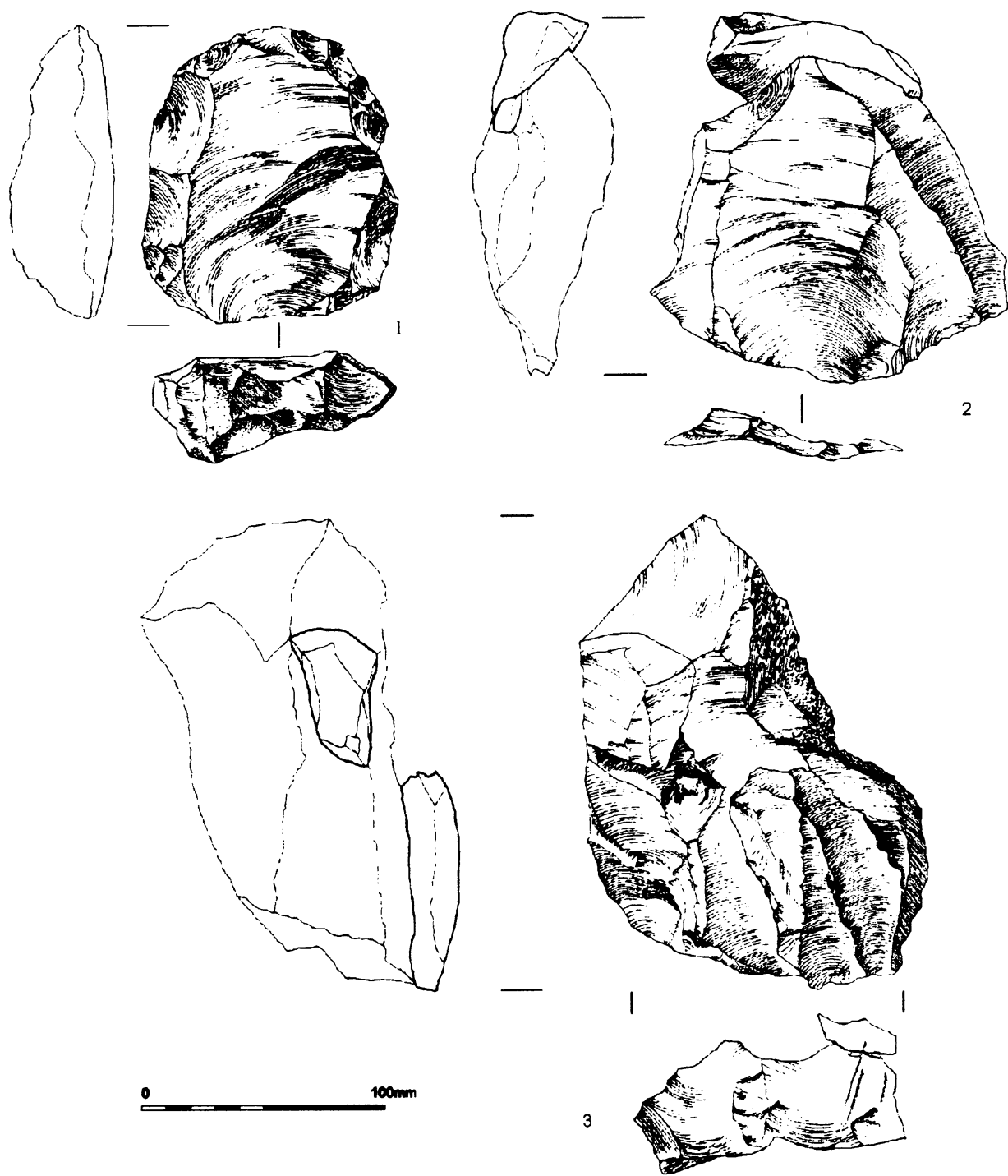


Fig. 9.
9. 1- lineal Levallois core; 9.2 – recurrent unipolar Levallois core; 9.3 – broken (?) Levallois core

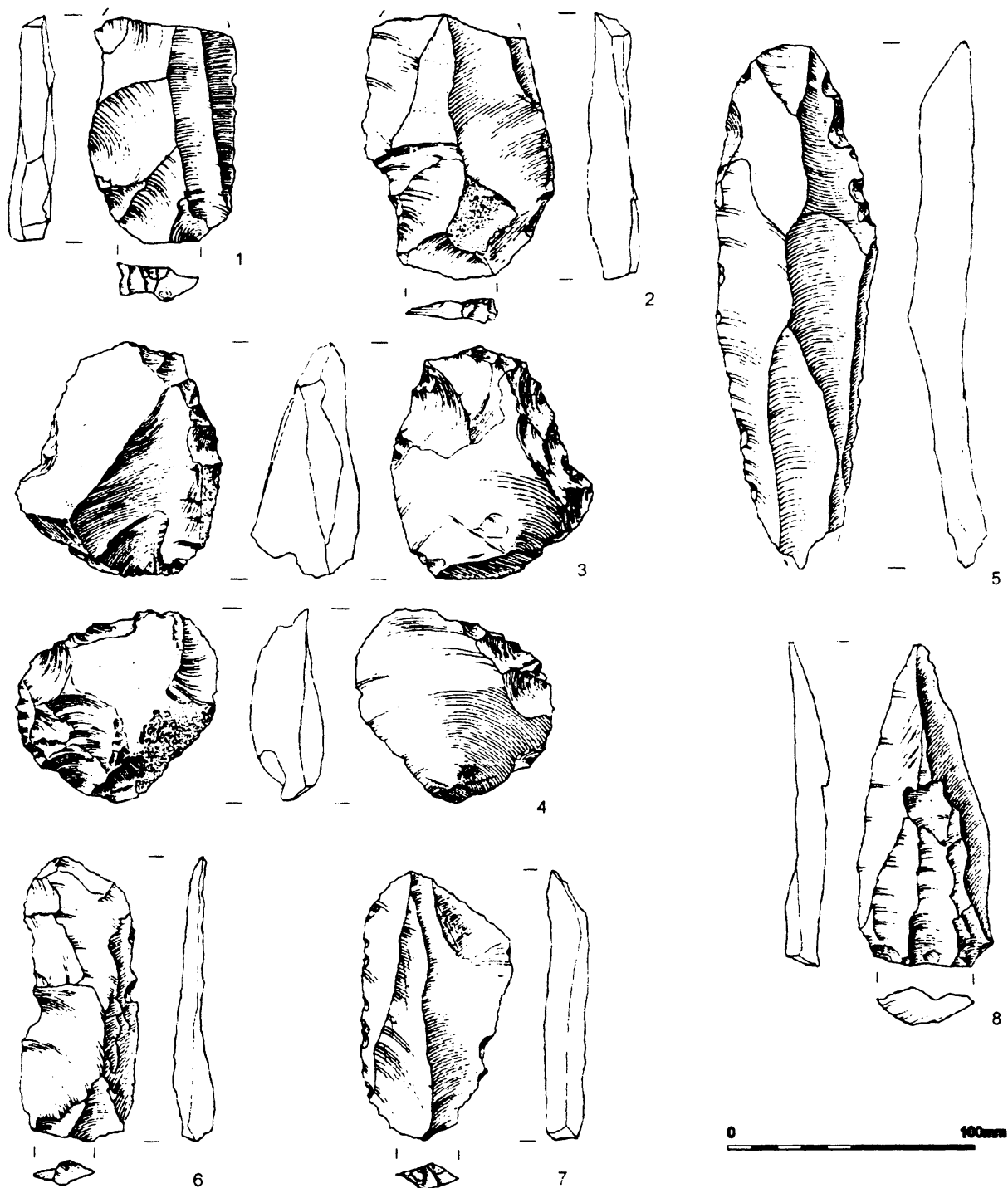


Fig. 10.

10.1 – *éclat débordant*; 10.2 – broken Levallois flake; 10.3 – Bifacial scraper; 10.4 – scraper with ventral retouch; 10.5 – Levallois blade; 10.6 & 10.7 – Levallois flakes (Warren Collection); 10.8 – Levallois point (Warren Collection)

THE PREHISTORIC SOCIETY

TABLE 5: SUMMARY FLAKE DATA

Metrical Data (in mm)		Butt Type	
<i>length</i>	mean: 49.61 ± 21.8	<i>Plain</i>	23 (19.8%)
	mode: 47; median: 48.5	<i>Dihedral</i>	5 (4.3%)
	range: 15-120	<i>faceted</i>	4 (3.4%)
<i>width</i>	mean: 45.47 ± 19.07	<i>marginal</i>	9 (7.7%)
	mode: 34; median 44	<i>cortical</i>	26 (22.4%)
	range: 14-105	<i>mixed</i>	12 (10.3%)
<i>thickness</i>	mean: 12.89 ± 8.50	<i>chapeau de gendarme</i>	1 (0.8%)
	mode: 9; median: 11.75	<i>broken</i>	36 (31.0%)
	range: 2-49		
<i>Dorsal Cortex (%)</i>		<i>Dorsal Scar Patterns</i>	45 (38.7%)
0	38 (32.7%)	<i>Unidirectional</i>	7 (6.0%)
1-20	31 (26.7%)	<i>Bidirectional</i>	44 (37.9%)
21-40	13 (11.2%)	<i>Multidirectional</i>	20 (17.2%)
41-60	11 (9.4%)	<i>None</i>	
61-80	6 (5.1%)		45:72 (39:61%)
81-100	17 (14.6%)	<i>Broken: Whole</i>	

flake data). A sample of the gravel, sieved through a 10 mm mesh, confirmed the visual observation that no significant micro-debitage was present. The paucity ofdebitage in the <20–30 mm size range, which numerically dominates experimentally produced flake populations (Schick 1986; Wenban-Smith *et al.* 2000), clearly shows that the assemblage has been winnowed by fluvial activity, although with only slight disturbance to the larger artefacts, as indicated by the refits. As most analyses concentrate on the larger element – by far the most useful in studying technological organisation – the paucity of micro-debitage need not overly detract from the value of the collection.

As the only technological strategy evident at the site is Levallois reduction, it is assumed that the majority of thedebitage has been generated via the preparation, exploitation, and reparation of Levallois cores. Interestingly in this case, the cortex data for the assemblage shows a similar distribution of cortex percentage states to some recently published experimental data on non-Levallois core reduction (Wenban-Smith *et al.* 2000); while there are differences in the actual percentages, the overall trend, which shows a U-shaped distribution, is the same. This suggests that, winnowing notwithstanding, fairly complete reduction sequences are present at the site, from raw material acquisition through to initialisation and exploitation, with the presence of an *éclat*

debordant testifying to the re-initialisation of flaking surfaces. Furthermore, the dorsal scar patterns on the flakes exhibit a complementary pattern to the types of working seen on the cores, with 38.7% showing working in a unidirectional pattern (ie, from the proximal only), 6% in a bidirectional pattern (from distal and proximal), and 37% in a multidirectional pattern, which would correspond with the working of unipolar and centripetal cores as seen at the site. There is one flake that could possibly be a biface thinning flake, it seems more likely to be a by-product of Levallois reduction, given the overall context.

Flake tools

Two flakes tools were recovered from the excavation (Figs 10.3 & 10.4). The first is a rather rough bifacially-worked scraper, with retouch to alternate faces on either lateral margin. It might alternatively be classed as a handaxe roughout. The second is a simple straight scraper with limited retouch to the ventral surface.

Refits

The post-excavation analysis revealed that a number of artefacts from the upper Crayford Gravel conjoin. LTC84/12, a flake with a faceted butt and broken in three pieces, refits with a broken cortical flake (LTC84/78), which was found 0.17 m away to the east and 0.22 m below it. Flake LTC84/94 refits with core LTC84/96, separated by 0.41 m horizontally and

0.06 m vertically, as does the unplotted broken flake LTC84/101 and the Levallois point LTC84/123 (discovered in a gravel sample). Two flakes also conjoin with core LTC84/97: LTC84/3, an unplotted broken flake, and flake LTC95/1022, which was found in the 1995 excavation and separated from the core by 3.10 m horizontally and *c.* 0.20 m vertically. Several snapped flakes can also be refitted. While this may not be as numerically impressive as the refits from Boxgrove (Roberts & Parfitt 1999) or several European Levallois sites (Dibble & Bar-Yosef 1995; Roebroeks *et al.* 1993), it demonstrates that the assemblage is, if not *in situ*, only minimally disturbed.

The Warren Collection

The collection amassed by Warren and Kennard (British Museum, Warren Collection) consists of 84 pieces (Table 4). These unfortunately lack a precise provenance although, judging from Warren's descriptions, they must have come from the Crayford Gravel (indeed it was Warren's description, as recorded by MacFadyen, that allowed the 'floor' to be relocated). Like the excavated sample, these are in fresh condition, show an incipient or slight patina, and are unstained. Some selection for larger and more impressive pieces seems to have taken place at some point in the history of this collection.

The collection includes seven cores, four of which are definite Levallois cores. Two Levallois operational schemes are evident, both slightly different from those already seen in the excavated sample. Two of the cores show radial preparation and unipolar recurrent exploitation. One is very small in size (57 x 56 x 38 mm) and retains a very small patch of cortex on the striking platform surface; it may represent the final phases of reduction of a once larger piece. The other two are recurrent centripetal Levallois cores, showing radial preparation and a series of non-preferential removals from around the core edge. At least one of these cores would, according to previous definitions of the Levallois, have been considered an unstruck tortoise core.

Although often regarded as discrete methods, some studies (eg, Dibble 1995; Bietti & Grimaldi 1995; Texier & Francisco-Ortega 1995; Jaubert & Farizy 1995, amongst others) have emphasised how Levallois cores may change from one schema to another during the course of continuous reduction, one noteworthy pattern being the transformation from polarised to centripetal preparation, and from

recurrent to lineal exploitation.

The other cores in the Warren Collection would not qualify as Levallois *sensu stricto*. Two can best be described as opposed platform cores. Both have been formed on cylindrical rods of flint, with platforms created by 1–3 steep removals at either end. Following this, both cores have been exploited using a series of parallel, blade-like removals from both platforms. In one case the distal ends of the opposing scars do not intersect, leaving a ridge of cortex that clearly demonstrates that no preparation of the flaking surface had been undertaken. The flaking exploits natural convexities, and while sharing the principles of hierarchically related surfaces and a plane of intersection, do not fulfill all the criteria of the Levallois Concept. In some respects they are technologically similar to the 'proto-Levallois' cores seen at the MIS 8 site at Botany Pit, Purfleet (Schreve *et al.* 2002), as well as those described from the MIS 5/4 site of Saint-Vaast-la-Hougue, France (Guette 2002). At the latter, the exploitation of natural convexities to produce more-or-less controlled flakes led Guette to argue that the Levallois Concept was overly restrictive in requiring specially prepared convexities (*cf* Chazan 1997). The final core has been formed on a large cortical flake and shows three removals at the proximal end (removing the original butt), which formed the striking platform for a single 'Janus' flake from the ventral surface (this might equally be classed as a *rabot* or simply a flaked-flake).

The debitage in the Warren Collection is clearly biased towards larger and/or Levallois flakes. The mean length is 68.55mm±28.86, and of the 68 flakes >200 mm, 10 are considered in the present study to be definite Levallois end-products, including an *éclat Levallois débordant*, a blade (Fig. 10.5), two flakes (Figs 10.6 & 10.7), and a Levallois point (Fig. 10.8). At least another eight might also, more equivocally, be classed as Levallois products. In concord with the cores, a variety of preparatory and exploitation modes are evident. The final piece from the collection is a leaf-shaped handaxe (Fig. 11). This shows a different preservational state to anything else from the tramway cutting, being slightly rolled and having a highly lustrous surface. It is doubtful whether this is truly associated with the main Levallois assemblage.

Overall synthesis

The overall assemblage therefore shows two modes of exploitation (lineal and recurrent) and two modes of

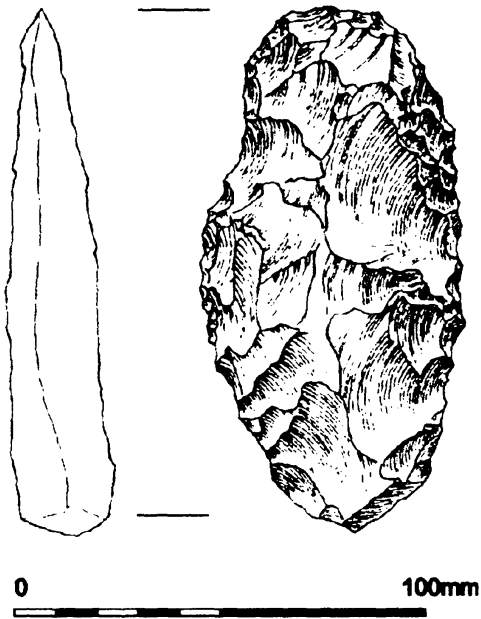


Fig. 11.
Handaxe (Warren Collection)

preparation (unipolar and radial) combined in four different operational schema.

- Radial preparation with lineal (preferential) exploitation.
- Radial preparation with centripetal recurrent exploitation.
- Radial preparation with unipolar recurrent exploitation.
- Unidirectional preparation with unipolar recurrent exploitation.

INTERPRETATIVE DISCUSSION

The geological context

The geological sequence containing and overlying the Palaeolithic assemblage is confirmed as a late Middle Pleistocene Thames terrace aggradation. It commenced with the deposition of the basal Crayford Gravel, laid down soon after the period of downcutting that separates the Corbets Tey terrace from the Mucking terrace level. According to recent interpretations of river terrace formation in response to Quaternary climatic fluctuation (Bridgland 1994; 2000; Bridgland & Maddy 1995; Bridgland & Allen

1996), this incision is likely to have occurred near the end of a cold (glacial) stage, perhaps enabled by the melting of permafrost at the glacial-interglacial transition, this providing a significant boost in fluvial discharge. The incision into the Chalk at West Thurrock is lined with substantial 'coombe rock' deposits, suggesting that at the time of the downcutting interglacial conditions had not yet arrived, so that the slopes remained unstable and mobile. The coarseness of the basal water-laid deposit, the Crayford Gravel (bed 1), suggests that it too was emplaced during the period of high discharge and unstable landscape, prior to the onset of the MIS 7 interglacial. There is little other environmental evidence from this basal bed. In the sections opened in 1984 and 1995 it contained none of the fossils that might be anticipated in an interglacial gravel, such as those at Swanscombe (Ovey 1964; Conway *et al.* 1996) and Purfleet (Schreve *et al.* 2002). The lower sand (bed 2) is thought to have been the source of part of the vertebrate material collected by Abbott, whereas the clayey silt 'brickearth' (bed 3) has yielded the differentially-preserved molluscan and small vertebrate assemblages described above and the pollen spectra recorded by Hollin (1977) and Gibbard (1994), both from this site and from the road cutting 0.9 km to the west. These are the only beds to have yielded fossils and, even then, they are only sparsely and patchily fossiliferous. This is particularly apparent in the case of bed 3, where only the lower parts are fossiliferous, thereby implying decalcification in the upper parts of the sequence.

The considerable thickness of the sand-silt-clay alternations (bed 4) that constitute much of the sequence in the northern part of the site is entirely lacking in fossils and must thus be interpreted purely on its sedimentology. None of the malacological evidence from bed 3 is suggestive of even the slightest brackish influence and although some of the fish taxa are tolerant of saline influence, there are no obligate marine species present in the assemblage. On the basis of sedimentological arguments put forward above, however, this part of the sequence (bed 2–4) is considered likely to have estuarine affinities. Furthermore, fine-grained deposits of this type are rare within the Thames terrace sequences further upstream, leading to the tentative suggestion that they might result from clay flocculation at the uppermost limit of estuarine influence, in response to a small increase in salinity. It is also known from the nearby

site at Aveley, which has a sequence broadly contemporaneous with that at West Thurrock (Schreve *et al.* in prep.), that this part of the Lower Thames valley was within the estuarine zone during part of the MIS 7 interglacial. It therefore seems likely, but not certain, that the uppermost part of the interglacial sequence in the tramway cutting was deposited near the fluvial-estuarine boundary at downstream end of the Lower Thames valley.

The West Thurrock Gravel, which overlies the interglacial sediments at the southern end of Lion Pit tramway cutting, represents a return to cold-climate conditions. Gibbard (1994; 1995) has interpreted this deposit as an early Devensian gravel, quite separate from the widespread Mucking Gravel, the dominant post-interglacial element of which occurs at exactly the same position within the Lower Thames terrace staircase. The Mucking Gravel, mapped as Floodplain Gravel on the original New Series Geological Survey maps of this area (Dewey *et al.* 1924; Dines & Edmunds 1925), was shown by Bridgland (1988) and Gibbard *et al.* (1988) to be a downstream continuation of the Taplow Gravel of the Middle Thames, one of the earliest of the Thames terraces to be named (Bromehead 1912). Gibbard (1985) established that the Taplow Gravel is of late Wolstonian age (*sensu* Mitchell *et al.* 1973). The gravel at West Thurrock was not separated from the remainder of the Mucking gravel by the Geological Survey mapping, but Gibbard's interpretation of the underlying interglacial sediments as Ipswichian necessitated a later age for the upper gravel at West Thurrock. Indeed, he has only identified this supposed post-Ipswichian gravel at sites where it overlies sediments that he has ascribed to the Ipswichian. All of the interglacial sediments listed above have been interpreted by other authors as pre-Ipswichian, however (Bridgland 1994; see above). If this alternative interpretation is accepted, the upper gravel at West Thurrock can be regarded as an integral part of the Taplow/Mucking Formation and the term West Thurrock Gravel adopted, as detailed above, as the name for the post-interglacial upper gravel member of this formation, which dates not from the early Devensian, but from MIS 6 (late Saalian).

The discovery of a soil complex in the uppermost deposits in Section 1 is of potential significance. It has been observed (above) that temperate-climate soil formation had taken place in the upper part of the interglacial sequence prior to it being capped by the

solifluction gravel of bed 6. If the last-mentioned dates from the Devensian, the soil processes affecting bed 4 must date from the Ipswichian (or earlier). Whether an Ipswichian age for this truncated soil requires the bed 4 sediments to be pre-Ipswichian, as other lines of evidence suggest, is uncertain. If bed 4 is correctly interpreted as estuarine in origin it must relate to the optimal part of whatever interglacial it represents. There may well have been sufficient time following the climatic optimum, during the waning phase of the interglacial, for the stabilisation of former estuarine mudflats and the formation of a brown-earth soil.

Biostratigraphy

As stated above, the position of the site within the Lower Thames terrace sequence, which has been interpreted as the result of glacial-interglacial climatic forcing (Bridgland 1994; 1998; 2000), provided the first indication that the interglacial deposits might be of pre-Ipswichian age (*cf* Sutcliffe 1975; 1976). The reappraisal of the vertebrate assemblage and the collection of new molluscan material have permitted this hypothesis to be tested. Amongst the small number of molluscan species present, *C. fluminalis* is considered to be of particular significance, since it is now generally accepted that this species was not present in western Europe in deposits post-dating MIS 7 (Keen 1990; 2001; Preece 1999; Meijer & Preece 2000). The interglacial sediments at the Lion Pit tramway cutting cannot therefore be any younger than that episode. The single ribbed fragment of *Pisidium*, tentatively identified as *P. clessini*, also indicates an age no younger than MIS 7, as this species is believed to have become extinct after that stage (Preece 1999).

The West Thurrock mammalian assemblage was attributed to the Ipswichian interglacial by Carreck (1972; 1976) on the basis of its similarity to those from Uphall Pit at Ilford and Crayford. At the time, both sites and their mammalian faunas (eg, Stuart 1976) were widely regarded as Last Interglacial in age (eg, West *et al.* 1964). More recently, these correlations were endorsed by Gibbard (1994; 1995) on the basis of further palynological analyses. However, it is now apparent that these sites, along with many others that were formerly attributed to a generalised 'Ipswichian' group, in fact belong to a pre-Ipswichian interglacial episode, widely correlated with MIS 7 (Sutcliffe 1975; Shotton 1983; Bowen *et al.* 1989; Bridgland 1994; Schreve 2001). It now seems

that palynological signatures from the successive interglacials correlated with MIS 7 and MIS 5e are highly similar. These episodes may, however, be separated on a number of other grounds, including terrace stratigraphy, mammalian and molluscan biostratigraphy, and amino acid geochronology. The clear implication is that the pollen record is insufficiently sensitive to differentiate between interglacials that are close together in time.

Although small, the composition of the West Thurrock mammalian assemblage and the presence of a number of biostratigraphically diagnostic species provide a clear indication of age. The Elephantidae are dominated by remains of mammoth (85% of the elephant specimens), compared with only 3.5% for straight-tusked elephant. The co-existence of these taxa, and the predominance of the former over the latter, is a consistent feature of MIS 7 assemblages, such as those from Ilford (Uphall) and Aveley, Essex (Schreve *et al.* in prep.), Stanton Harcourt, Oxfordshire (Buckingham *et al.* 1996), and the Lower Channel at Marsworth, Buckinghamshire (Murton *et al.* 2001), and is considered to reflect the preponderance of grassland over more forested conditions during this part of the interglacial. Mammoths are unknown from any other post-Anglian Middle Pleistocene interglacial in Britain (Schreve 2001), although they are present in the later parts of MIS 5 (post-dating the MIS 5e climatic optimum) at Bacon Hole, Gower (Currant & Jacobi 2001). An important biostratigraphical feature of mammoths from the penultimate interglacial is that their molars have a relatively low plate count of 19–22 plates in the M3, compared to the usual Devensian *M. primigenius*, which has an average of about 24 plates in the M3 (Falconer in Murchison 1868). In this respect, they resemble the early Middle Pleistocene *Mammuthus trogontherii*, rather than *M. primigenius*. In addition, although post-Anglian/Elsterian mammoth populations continue to show a similar plate number and hypsodonty index to *M. trogontherii*, there is a noticeable broad trend towards reduced size (Lister & Sher 2001). This can be seen clearly in MIS 7 mammoth populations in Britain, such as at Ilford, where the same plate count is retained, although size reduction in the tooth continues still further. The combination of small size and relatively low plate count has long been noted as a consistent feature in the Ilford population (Davies 1874; Adams 1877–81; Sandford 1924; Moir &

Hopwood 1939) and at other interglacial sites, now widely attributed on several different lines of evidence to the MIS 7 interglacial, including Brundon, Suffolk (Moir & Hopwood 1939), the Lower Channel at Marsworth, Northfleet, Stanton Harcourt, and Stoke Tunnel (Layard 1912). The West Thurrock specimens compare closely to those from Ilford, although no third molars are present.

The presence of *Stephanorhinus kirchbergensis* at West Thurrock is also extremely significant, since this species is unknown from deposits of Ipswichian age (Stuart 1976; 1982). Its occurrence has been further verified at Ilford (*contra* Stuart 1976) and Crayford (Schreve 1997), thereby corroborating the pre-Ipswichian age already suggested for these deposits and demonstrating that *S. kirchbergensis* was a genuine component of the MIS 7 fauna. The West Thurrock assemblage is further differentiated from that of the Ipswichian Interglacial by the presence of horse, an animal that is unknown from deposits of true Last Interglacial age (MIS 5e) in Britain (Sutcliffe 1995; Schreve 2001) yet present in association with mammoth during the preceding interglacial. The overall composition of the mammalian assemblage therefore suggests an age within the penultimate (MIS 7) interglacial.

The Palaeolithic assemblage and the chronology of the Levallois in north-west Europe

The limited opportunities for investigation of the artefact-bearing Crayford Gravel at West Thurrock have enabled confirmation of Warren's assertion that this is an important Levallois site. The use of Levallois technique at the Lion Pit tramway cutting was confirmed by the occurrence of three unequivocal Levallois cores and several Levallois end-products in the excavated sample, all of which conform to recent technological definitions. Furthermore, it is apparent that the existing British Museum assemblage was collected according to a biased strategy. The average length of the pieces exceeds 70 mm, perhaps revealing that only large and/or diagnostic specimens were collected.

It is also clear that Warren had some justification for calling this a 'working floor', although his own conclusion that the site was *in situ* was presumably based on observations of the excellent condition of the material, as there is nothing to suggest that he realised that refitting material was present. Indeed, none of the material from his collections now in the British

2. D. Schreve *et al.* A LEVALLOIS KNAPPING SITE AT WEST THURROCK, LOWER THAMES, UK

Museum is conjoinable, but the artefacts collected under controlled conditions during 1984 and 1995 include at least eight refits. The occurrence of refits implies minimal disturbance of the larger material subsequent to the knapping activity, even though the coarse gravel context indicates a high-energy depositional environment.

The fluvial context helps explain the absence of micro-debitage of the type that would be expected in a truly undisturbed knapping scatter; in the Lion Pit assemblage the smallest flake size rarely falls below 20 mm, even in the sieved residues, indicating that the micro-debitage and many of the smaller flakes have been dispersed. The finerdebitage was probably winnowed away by river flow subsequent to the knapping activity, prior to final burial of the Crayford Gravel by the Aveley Silts and Sands. The degree to which the surviving artefact scatter has been moved by river flow is uncertain. The full extent of the scatter cannot be calculated on the basis of the area excavated, although the condition and presence of refits clearly shows that the larger material has undergone only minimal lateral and vertical movement as a result of post-depositional influences.

The most plausible interpretation of site formation processes for the lithic assemblage is as follows:

- The edge of the Thames channel formed a focus of activity for early Middle Palaeolithic groups during the MIS 8–7 transition, this channel edge having a coarse gravel ‘beach’ that contained suitable raw material for tool making.
- Large flint nodules, both from the gravel and, in all probability, freshly eroded from the Chalk, were used exclusively for Levallois flaking. Although a handaxe was recovered by Warren, the flakes display few of the characteristics associated with handaxe thinning and shaping. Full Levallois reduction sequences were carried out here, from raw material acquisition, through preparation, exploitation and discard of the cores and waste flakes on the river beach, to the export of selected blanks for use elsewhere.
- Subsequent moderate flow winnowed the finerdebitage from the gravel beach and partly rearranged the largerdebitage.
- The main thickness of overburden was emplaced during the subsequent MIS 7 interglacial, much of it in an upper estuarine environment, with minor additions to and modifications of the upper part of the sequence during later episodes

- A few artefacts from the upper Crayford Gravel were vertically displaced, filtering through the intermediate sands and coming to rest on the lower Crayford Gravel. The winnowing process might have instigated such displacement, or it might have resulted from trampling (by animals or knappers).

The interpretation of the Lion Pit Palaeolithic assemblage and its geological context and, in particular, the age of the latter is in full accord with the modern view that Levallois appeared in Britain and north-west Europe during the late Middle Pleistocene. Indeed, it is widely accepted that the appearance of technologically diverse Levallois technology occurred at some time during MIS 9–7 (Bridgland 1994; 1996; 1998; Dibble & Bar-Yosef 1995; Wymer 1999), while an incipient form may have developed in Europe somewhat earlier (Tuffreau 1995; White & Ashton 2003). In Britain a number of significant Levallois sites belong to this period, notable amongst which is Purfleet (Schreve *et al.* 2002), only 3 km from Lion Pit. Here, an early MIS 8 ‘proto-Levallois’ or simple prepared core technology (Wymer 1968; White & Ashton 2003) occurs within the uppermost deposits (the Botany Gravel of Schreve *et al.* 2002) of the Corbets Tey Formation, which forms the terrace above that represented at West Thurrock. It is thought that Purfleet, together with sites such as Yiewsley, West Drayton, and Creffield Road in the Middle Thames (Ashton *et al.* 2003), Sturry in the Kentish Stour (Bridgland *et al.* 1998), and (more contentiously) Cuxton in the Medway (Bridgland 2003), record some of the earliest occurrences of the Levallois technique in Britain.

There are several other sites in the Lower Thames valley where basal Mucking Formation deposits have yielded Levallois artefacts, including the most celebrated of all British Levallois localities, the Bakers Hole/Northfleet/Ebbsfleet complex in north Kent (Bridgland 1994; Wenban-Smith 1995). Aveley, where the interglacial part of the Mucking Formation is best developed, has yielded a small number of artefacts, including a Levallois core (Schreve *et al.* in prep.), indicating the continuation of this technology into MIS 7. At Crayford, these same Aveley Member interglacial deposits have yielded primary-context Levallois material, found during manual excavation of the many brick pits there (Spurrell 1880; Chandler 1916; Kennard 1944). Importantly, the record from

Crayford reveals that human (Levallois) occupation continued into the MIS 7 interglacial, since conjoinable artefacts were found there (Spurrell 1880) within the body of the 'Crayford brickearth' (= Aveley Silts and Sands Member). Sediments of similar age in Suffolk have also produced small assemblages, including Levallois elements, for example Brundon, Stoke Tunnel/Maidenhall, and Stutton/Harkstead (Wymer 1985; Schreve 1997). Away from south-eastern England, and even from sources of flint, a Levallois assemblage from Pontnewydd Cave, Clwyd, has been dated to MIS 7 by multi-proxy means (Green 1984).

Elsewhere in Europe a similar pattern is evident. Early prepared core technologies, some reminiscent of the 'proto-Levallois' from Purfleet, have been reported from a number of Middle Pleistocene sites, of MIS 8 age or older. For example, the early Saalian site (MIS 8) site of Markkleeberg, Germany (Baumann & Mania 1983; Svoboda 1989) contains a number of cores showing similar technology, alongside other Levallois methods; Argoeuves, France (Lower Terrace Complex of the Somme, MIS 8) has yielded unidirectional and bidirectional prepared cores that were used to produce a series of laminar blanks (Tuffreau 1982; 1995); Korolevo, Ukraine, has produced proto-Levallois cores from levels that have been dated by thermoluminescence to $>360 \pm 50$ ka (Adamenko & Gladiline 1988); while at Orgnac 3, France, which is dated to 350–300 kya, the investigators described a simple form of polarised prepared core technology, the configuration of which suggested a system that was controlled but with rules that were 'not fully standardised' (Moncel & Combier 1992). By MIS 8–7, at the inferred time of manufacture of the Lion Pit assemblage, a complex, diverse and unequivocal Levallois technology was ubiquitous throughout much of north-west Europe (*cf* Dibble & Bar-Yosef 1995).

The confirmation of a latest MIS 8 age for the Levallois assemblage at West Thurrock also conforms with recent suggestions that Levallois technique was prominent in Britain only during a relatively brief interval within the late Middle Pleistocene, from terminal MIS 9 to MIS 7 (Ashton *et al.* 2003). This correlation is based on multiple independent dating proxies and is not archaeologically driven. The reason for the absence of Levallois technology during the period MIS 6–4, when there is good evidence for its use elsewhere in the Neanderthal world, relates to an occupational hiatus in Britain, a period of human

abandonment that lasted approximately 100,000 years (Sutcliffe 1995; Bridgland 1998; Ashton & Lewis 2002). When Neanderthals returned to Britain during MIS 3 (Currant & Jacobi 2001), the technology they brought with them was Mousterian of Acheulean Tradition with a low Levallois index but rich in handaxes (White & Jacobi 2002), similar to that practised by Neanderthal populations in some neighbouring regions of north-west Europe.

CONCLUSIONS

The small assemblage collected under controlled conditions, supplemented by the material collected many years earlier by Warren, confirms that a flint knapping site with Levallois technique is preserved at West Thurrock. The new assemblage includes three Levallois cores and at least 10 Levallois products from amongst 144. The older collections are clearly biased towards more impressive specimens and include four Levallois cores and up to 14 or more Levallois end-products amongst only 84 pieces.

Dating by multiproxy means of the Thames terrace sediments containing and overlying the archaeology is critical to the establishment of the age of the West Thurrock Palaeolithic assemblage. The fluvial deposits span a period of deposition during MIS 8–6 (mid-late Saalian), with the underlying 'coombe rock' and the basal artefact-bearing Crayford Gravel attributed to the latter part of MIS 8. The overlying interglacial sequence, which is considered to be part of the Aveley Silts and Sands Member, is thought to include sediments accumulated under estuarine conditions. This member is attributed to MIS 7, an interpretation that is based on terrace lithostratigraphy, mammalian and molluscan biostratigraphy and amino acid racemisation analyses. The cold-climate West Thurrock Gravel completes the water-laid sequence and is attributed to MIS 6. The complete set of fluvio-estuarine Quaternary sediments is regarded as part of the Taplow/Mucking Formation (*sensu* Bridgland 1994; 1995).

The human occupation recorded at the site can have occurred no later than the very end of MIS 8, during the transition into the succeeding interglacial. This is one of a number of sites in the Lower Thames and further afield that record Levallois occupation during this part of the Pleistocene, thereby attesting to hominin occupation in environments and climates outside those of interglacial optima. Artefacts made

using Levallois technique first appear in the uppermost deposits of the Lynch Hill/Corbets Tey Formation of the Thames, in the gravels laid down following the MIS 9–8 transition. Several sites, including West Thurrock, reveal the occurrence of Levallois in deposits recording the MIS 8–7 transition; at some, such as Crayford, Levallois knapping is seen to have persisted during the MIS 7 interglacial. Although artefacts have not been recorded from the interglacial deposits, the presence of putative cutmarked bone suggests the continued presence of Neanderthals in the valley at this time.

Acknowledgements: DCS and DRB acknowledge the support of the Leverhulme Trust during a project 'Mammalian biostratigraphy of north-west European rivers'. English Nature and Chafford Hundred plc are thanked for their co-operation in allowing us to clean sections and in undertaking restoration works necessary to make this important site accessible. The cartography unit in the Department of Geography at the University of Durham is thanked for the production of Figures 1–4. Sue May (Department of Geography, Royal Holloway) is thanked for Figure 6 and the SEM unit at the Natural History Museum (particularly Chris Jones) is gratefully acknowledged for Figure 7. All lithics were illustrated by Phil Harding. This project is a contribution to UNESCO IGCP 449 and 518 and to the Leverhulme Trust-funded Ancient Human Occupation of Britain project. Aminoacid geochronology was funded by the Aggregates Levy Sustainability Fund.

BIBLIOGRAPHY

- Abbott, W.J.L. 1890. Notes on some Pleistocene sections in and near London. *Proceedings of the Geologists' Association* 11, 473–80
- Adamenko, O.M. & Gladiline, E.V. 1989. Korolevo, un des plus anciens habitats Acheuléens et Moustériens de Transcarpatie Soviétique. *L'Anthropologie* 93(4), 689–712
- Adams, A.L. 1877–81. *Monograph of the British Fossil Elephants*. London: Palaeontographical Society
- Ashton, N.M. & Lewis, S.G. 2002. Deserted Britain: declining populations in the British late Middle Pleistocene. *Antiquity* 76, 388–96
- Ashton, N., Jacobi, R. & White, M. 2003. The dating of Levallois sites in west London. *Quaternary Newsletter* 99, 25–32
- Avery, B.W. 1980. *Soil classification for England and Wales (Higher Categories)*. Harpenden: Soil Survey Technical Monograph 14
- Avery, B.W. 1985. Argillic horizons and their significance in England and Wales. In Boardman, J. (ed.), *Soils and Quaternary Landscape Evolution*, 69–86. Chichester: Wiley
- Baumann, W. & Mania, D. 1983. *Die Paläolithischen Neufunde von Markkleebera bei Leibzig*. Berlin: VEB Deutscher Verlag der Wissenschaften
- Bietti, A. & Grimaldi, S. 1995. Levallois debitage in Central Italy: technical achievements and raw material procurement. In Dibble & Bar-Yosef (eds) 1997, 25–142
- Boëda, E. 1986. *Approche technologique du concept Levallois et évaluation de son champ d'application*. Thèse de IIIème Cycle, Université de Paris
- Boëda, E. 1995. Levallois: a volumetric construction, methods, a technique. In Dibble & Bar-Yosef (eds) 1995, 41–67
- Boëda, E., Geneste, J.-M. & Meignen, L. 1990. Identification de chaînes opératoires lithiques du Paléolithique Ancien et Moyen. *Paléo* 2, 43–80
- Bowen, D.Q. (ed.). 1999. *A Revised Correlation of Quaternary Deposits in the British Isles*. London: Geological Society of London Special Report 23
- Bowen, D.Q., Hughes, S., Sykes, G.A. & Miller, G.M. 1989. Land-sea correlations in the Pleistocene based on isoleucine epimerization in non-marine molluscs. *Nature* 340, 49–51
- Bowen, D.Q., Sykes, G.A., Maddy, D., Bridgland, D.R. & Lewis, S.G. 1995. Aminostratigraphy and amino acid geochronology of English lowland valleys: the Lower Thames in context. In Bridgland *et al.* (eds) 1995, 61–3
- Bridgland, D.R. 1985. Pleistocene sites in the Thames Avon system. *Earth Science Conservation* 22, 36–9
- Bridgland, D.R. 1988. The Pleistocene fluvial stratigraphy and palaeogeography of Essex. *Proceedings of the Geologists' Association* 99(4), 291–314
- Bridgland, D.R. 1994. *Quaternary of the Thames*. London: Chapman & Hall
- Bridgland, D.R. 1995. The Quaternary sequence of the eastern Thames basin: problems of correlation. In Bridgland *et al.* (eds) 1995, 35–52
- Bridgland, D.R. 1996. Quaternary river terrace deposits as a framework for the Lower Palaeolithic record. In Gamble, C. & Lawson, A., *The English Palaeolithic Reviewed*, 23–39. Salisbury: Trust for Wessex Archaeology
- Bridgland, D.R. 1998. The Pleistocene history and early human occupation of the River Thames valley. In Ashton, N., Healey, F. & Pettitt, P. (eds), *Stone Age Archaeology. Essays in Honour of John Wymer*, 29–37. Oxford: Oxbow Monograph 102
- Bridgland, D.R. 2000. River terrace systems in north-west Europe: an archive of environmental change, uplift and early human occupation. *Quaternary Science Reviews* 19, 1293–303
- Bridgland, D.R. 2003. The evolution of the River Medway, SE England, in the context of Quaternary palaeoclimate and the Palaeolithic occupation of NW Europe. *Proceedings of the Geologists' Association* 114, 23–48
- Bridgland, D.R. & Allen, P. 1996. A revised model for terrace formation and its significance for the lower Middle Pleistocene Thames terrace aggradations of north-east Essex, U.K. In Turner, C. (ed.), *The Early Middle Pleistocene in Europe*, 121–34. Rotterdam: Balkema

- Bridgland, D.R. & Harding, P. 1993. Middle Pleistocene deposits at Globe Pit, Little Thurrock, and their contained Clactonian industry. *Proceedings of the Geologists' Association* 104, 263–83
- Bridgland, D.R. & Harding, P. 1994. Lion Pit tramway cutting (West Thurrock; TQ 598783). In Bridgland, D.R. *Quaternary of the Thames*, 237–51. London: Chapman & Hall, Geological Conservation Review Series, Joint Nature Conservation Committee
- Bridgland, D.R. & Harding, P. 1995. Lion Pit Tramway Cutting (West Thurrock; TQ 598783). In Bridgland, D.R., Allen, P. & Haggart, B.A. (eds.), *The Quaternary of the Lower Reaches of the Thames*, 217–29. Durham: Field Guide, Quaternary Research Association
- Bridgland, D.R. & Maddy, D. 1995. River Terraces as records of Quaternary Climate Oscillation. *Programme with Abstracts*, 37. Berlin: INQUA 14
- Bridgland, D.R., Allen, P. & Haggart, B.A. (eds). 1995. *The Quaternary of the Lower Reaches of the Thames*. Durham: Quaternary Research Association Field Guide
- Bridgland, D.R., Schreve, D.C., Keen, D.H. & White, M.J. 1998. Quaternary drainage of the Kentish Stour. In Murton, J.B., Whiteman, C.A., Bates, M.R., Bridgland, D.R., Long, A.J., Roberts, M.B. & Waller, M.P. (eds), *The Quaternary of Kent & Sussex*, 39–54. London: Quaternary Research Association Field Guide
- Bridgland, D.R., Schreve, D.C., Allen, P. & Keen, D.H. 2003. Key Middle Pleistocene localities of the Lower Thames: site conservation issues, recent research and report of a Geologists' Association excursion, 8th July, 2000. *Proceedings of the Geologists' Association* 114, 211–25
- Bromehead, C.E.N. 1912. On diversions of the Bourne near Chertsey. *Summary of Progress, Geological Survey of Great Britain* for 1911, 74–7
- Buckingham, C., Roe, D. & Scott, K. 1996. A preliminary report on the Stanton Harcourt Channel Deposits (Oxfordshire, England): geological context, vertebrate remains and palaeolithic stone artefacts. *Journal of Quaternary Science* 11, 397–415
- Burchell, J.P.T. 1933. The Northfleet 50 ft. submergence later than the Coombe Rock of the post-Early Mousterian times. *Archaeologia* 83, 67–91
- Carreck, J.N. 1972. *Chronology of the Quaternary Deposits of south-east England, with Special Reference to their Vertebrate Faunas*. Unpublished M.Phil. thesis, University of London.
- Carreck, J.N. 1976. Pleistocene mammalian and molluscan remains from 'Taplow' Terrace deposits at West Thurrock, near Grays, Essex. *Proceedings of the Geologists' Association* 87, 83–92
- Chandler, R.H. 1916. The implements and cores of Crayford. *Proceedings of the Prehistoric Society of East Anglia* 2, 240–8
- Chazan, M. 1997. Redefining Levallois. *Journal of Human Evolution* 33, 719–35
- Clayton, F.M. 1996. *Palaeo-argillic Soils in South-east England*. Unpublished Ph.D Thesis, University of London
- Conway, B., McNabb, J. & Ashton, N. (1996). *Excavations at Barnfield Pit, Swanscombe, 1968–72*. London: British Museum Occasional Paper 94
- Currant, A.P. & Jacobi, R.M. 2001. A formal mammalian biostratigraphy for the Late Pleistocene of Britain. *Quaternary Science Reviews* 20, 1707–16.
- Davies, W. 1874. *Catalogue of the Pleistocene Vertebrata from the Neighbourhood of Ilford, Essex, in the Collection of Sir Antonio Brady*. London: printed for private circulation
- Dewey, H. 1932. The Palaeolithic deposits of the Lower Thames Valley. *Quarterly Journal of the Geological Society of London* 88, 35–56
- Dewey, H., Bromehead, C.E.N., Charwin, C.P. & Dines, H.G. 1924. *The Geology of the Country around Dartford*. London: Memoir of the Geological Survey of Great Britain
- Dibble, H. 1995. Biache-Saint-Vaast, Level IIa: a comparison of approaches. In Dibble & Bar-Yosef (eds) 1995, 93–116
- Dibble H.I. & Bar-Yosef, O. (eds). 1995. *The Definition and Interpretation of Levallois Technology*. Madison: Prehistory Press. Monographs in World Archaeology 23
- Dibley, G.F. & Kennard A.S. 1916. Excursion to Grays. *Proceedings of the Geologists' Association* 27, 103–5
- Dines, H.G. & Edmunds, F.H. 1925. *The Geology of the Country around Romford*. London: Memoir of the Geological Survey of Great Britain
- Falconer, H., in Murchison, C. (ed.). 1868. *Palaeontological Memoirs and Notes of the late Hugh Falconer. Volume II*. London: Hardwicke
- Gibbard, P.L. 1985. *The Pleistocene History of the Middle Thames Valley*. Cambridge: University Press
- Gibbard, P.L. 1994. *Pleistocene History of the Lower Thames Valley*. Cambridge: University Press
- Gibbard, P.L. 1995. Palaeogeographical evolution of the Lower Thames Valley. In Bridgland *et al.* (eds) 1995, 5–34
- Gibbard, P.L. 1999. The Thames valley, its tributary, valleys and their former courses. In Bowen (ed.) 1999, 45–58
- Gibbard P.L., Whiteman, C.A. & Bridgland, D.R. 1988. A preliminary report on the stratigraphy of the Lower Thames valley. *Quaternary Newsletter* 56, 1–8
- Green, H.S. 1984. *Pontnewydd Cave. A Lower Palaeolithic Hominid Site in Wales: the first report*. Cardiff: National Museum of Wales
- Guette, C. 2002. Révision critique du concept de débitage Levallois à travers l'étude du gisement Moustérien de Saint-Vaast-la-Hougue/le Fort (chantiers I-III et II, niveaux inférieurs) (Manche, France). *Bulletin de la Société Préhistorique Française* 99(2) 238–48
- Hill, R.L. 1965. Hydrolysis of proteins. *Advances in Protein Chemistry* 20, 37–107
- Hinton, M.A.C. 1901. Excursion to Grays Thurrock. *Proceedings of the Geologists' Association* 17, 141–4
- Hinton, M.A.C. 1910. A preliminary account of the British voles and lemmings; with some remarks on the Pleistocene climate and geography. *Proceedings of the Geologists' Association* 21, 489–507
- Hinton, M.A.C. & Kennard, A.S. 1900. Contributions to the Pleistocene geology of the Thames Valley, I. The Grays Thurrock area, part 1. *Essex Naturalist* 11, 336–70
- Hollin, J.T. 1977. Thames interglacial sites, Ipswichian sea levels and Antarctic ice surges. *Boreas* 6, 33–52

- Hollin, J.T. 1996. Review Essay. *Arctic and Alpine Research* 28, 529–31
- Jaubert, J. & Farizy, C. 1995. Levallois debitage: exclusivity, absence or co-existence with other operative schemes (Garonne Basin, SW France). In Dibble & Bar-Yosef (eds) 1995, 227–48
- Kaufman, D.S. & Manley, W.F. 1998. A new procedure for determining DL amino acid ratios in fossils using reverse phase liquid chromatography. *Quaternary Science Reviews* 17, 987–1000
- Keen, D.H. 1990. Significance of the record provided by Pleistocene fluvial deposits and their included molluscan faunas for palaeoenvironmental reconstruction and stratigraphy: case studies from the English Midlands. *Palaeogeography, Palaeoclimatology, Palaeoecology* 80, 25–34
- Keen, D.H. 2001. Towards a late Middle Pleistocene non-marine molluscan biostratigraphy for the British Isles. *Quaternary Science Reviews* 20, 1657–65
- Kemp, R.A. 1987. The interpretation and environmental significance of a buried Middle Pleistocene soil near Ipswich Airport, Suffolk, England. *Philosophical Transactions of the Royal Society London B* 317, 365–91
- Kennard, A.S. 1916. The Pleistocene succession in England. *Proceedings of the Prehistoric Society of East Anglia* 2, 249–67
- Kennard, A.S. 1944. The Crayford Brickearths. *Proceedings of the Geologists' Association* 55, 121–69
- Kerney, M.P. 1999. *Atlas of the Land and Freshwater Molluscs of Britain and Ireland*. Colchester: Harley
- Layard, N.F. 1912. Animal remains from the Railway Cutting at Ipswich. *Proceedings of the Suffolk Institute of Archaeology and Natural History* 14, 59–68
- Lister, A.M. & Sher, A.V. 2001. The Origin and Evolution of the Woolly Mammoth. *Science* 294, 1094–7
- McCarroll, D. 2002. Amino-acid geochronology and the British Pleistocene: secure stratigraphical framework or a case of circular reasoning? *Journal of Quaternary Science* 17, 647–51
- Meijer, T. & Preece, R.C. 2000. A review of the occurrence of *Corbicula* in the Pleistocene of north-west Europe. *Geologie en Mijnbouw* 79, 241–56
- Miller, G.H., Hollin, J.T. & Andrews, J. 1979. Aminostratigraphy of UK Pleistocene deposits. *Nature* 281, 539–43
- Mitchell, G.F., Penny, L.F., Shotton, F.W. & West, R.G. (1973). *A Correlation of Quaternary Deposits in the British Isles*. London: Geological Society of London Special Report 4
- Moir, J.R. & Hopwood, A.T. 1939. Excavations at Brundon, Suffolk (1935–37). *Proceedings of the Prehistoric Society* 5, 1–32
- Moncel, M.-H. & Combier, J. 1992. L'outillage sur éclat dans l'industrie lithique du site Pléistocène moyen d'Ornac 3 (Ardèche, France). *L'Anthropologie* 96, 5–48
- Morris, J. 1836. On a freshwater deposit containing mammalian remains, recently discovered at Grays, Essex. *Magazine of Natural History Series* 1(9), 261–4
- Murton, J.B., Baker, A., Bowen, D.Q., Caseldine, C.J., Coope, G.R., Currant, A.P., Evans, J.G., Field, M.H., Green, C.P., Hatton, J., Ito, M., Jones, R.L., Keen, D.H., Kerney, M.P., McEwan, R., McGregor, D.F.M., Parish, D., Schreve, D.C., Smart, P.L. & York, L.L. 2001. A late Middle Pleistocene temperate-periglacial-temperate sequence (Oxygen Isotope Stages 7–5e) near Marsworth, Buckinghamshire, UK. *Quaternary Science Reviews* 20, 1787–1825
- Ovey, C.D. (ed.). 1964. *The Swanscombe skull. A Survey of Research on a Pleistocene site*. London: Royal Anthropological Institute Occasional Paper 20
- Palmer, S. 1975. A Palaeolithic site at North Road, Purfleet, Essex. *Transactions of the Essex Archaeological Society* 7, 1–13
- Parkin, R. A., Rowley-Conwy, P. & Serjeantson, D. 1986. Late Palaeolithic exploitation of horse and red deer at Gough's Cave, Cheddar Somerset. *Proceedings of the University of Bristol Spelaeological Society* 17, 311–30
- Penkman, K.E.H. 2005. *Amino Acid Geochronology: a closed system approach to test and refine the UK model*. Unpublished PhD thesis, University of Newcastle
- Preece, R.C. 1999. Mollusca from last interglacial fluvial deposits of the River Thames at Trafalgar Square, London. *Journal of Quaternary Science* 14, 77–89
- Roberts, M.B. & Parfitt, S.A. 1999. *Boxgrove: a Middle Pleistocene hominid site at Eartham Quarry, Boxgrove, West Sussex*. London: English Heritage
- Roe, D.A. 1981. *The Lower and Middle Palaeolithic Periods in Britain*. London: Routledge & Kegan Paul
- Roebroeks, W., De Loecker, D., Hennekens, P. & Iperan, M. van. 1993. On the archaeology of the Maastricht-Belvédère pit. *Mededelingen Rijks Geologische Dienst* 47, 69–80
- Salvador, A. 1994. *International Stratigraphic Guide. A Guide to Stratigraphic Classification, Terminology, and Procedure*. The International Union of Geological Sciences and the Geological Society of America (2nd edition)
- Sandford, K.S. 1924. The river gravels of the Oxford district. *Quarterly Journal of the Geological Society of London* 80, 113–79
- Schick, K. 1986. *Stone Age Sites in the Making: experiments in the formation and transformation of archaeological occurrences*. Oxford: British Archaeological Report S314
- Schreve, D.C. 1997. *Mammalian Biostratigraphy of the Later Middle Pleistocene in Britain*. Unpublished Ph.D. thesis, University of London
- Schreve, D.C. 2001. Differentiation of the British late Middle Pleistocene interglacials: the evidence from mammalian biostratigraphy. *Quaternary Science Reviews* 20, 1693–1705
- Schreve, D.C., Bridgland D.R., Allen, P., Blackford, J.J., Gleed-Owen, C.P., Griffiths, H.I., Keen, D.H. & White, M.J. 2002. Sedimentology, palaeontology and archaeology of late Middle Pleistocene River Thames terrace deposits at Purfleet, Essex, UK. *Quaternary Science Reviews* 21, 1423–64

- Shotton, F.W. 1983. United Kingdom contribution to the I.G.C.P.; Project 24, Quaternary Glaciations of the Northern Hemisphere. Interglacials after the Hoxnian in Britain. Report by a working group chaired by Professor F.W. Shotton. *Quaternary Newsletter* 39, 19–25
- Smith, R.A. 1911. A Palaeolithic industry at Northfleet, Kent. *Archaeologia* 62, 515–32
- Smith, R.A. 1923. Prehistoric Man in Kent. *South East Naturalist* 28, 32–7
- Spurrell, F.J.C. 1880. On the discovery of the place where Palaeolithic implements were made at Crayford. *Quarterly Journal of the Geological Society of London* 36, 544–8
- Stuart, A.J. 1976. The history of the mammal fauna during the Ipswichian/Last interglacial in England. *Philosophical Transactions of the Royal Society of London* B276, 221–50
- Stuart, A.J. 1982. *Pleistocene Vertebrates in the British Isles*. London & New York: Longman
- Sutcliffe, A.J. 1975. A hazard in the interpretation of glacial-interglacial sequences. *Quaternary Newsletter* 17, 1–3
- Sutcliffe, A.J. 1976. Reply to R.G. West on 'The British Glacial-Interglacial Sequence'. *Quaternary Newsletter* 18, 1–7
- Sutcliffe, A.J. 1995. Insularity of the British Isles 250 000–30 000 years ago: the mammalian, including human, evidence. In Preece, R.C. (ed.), *Island Britain: a Quaternary perspective*. London: Geological Society Special Publication 96, 127–40
- Svoboda, J. 1989. Middle Pleistocene adaptation in central Europe. *Journal of World Prehistory* 3, 33–70
- Texier, P.-J. & Franciso-Ortega, I. 1995. Main technological and typological characteristics of the lithic assemblage from Level 1 at Bérigoule (Murs-Vaucluse). In Dibble & Bar-Yosef (eds) 1995, 213–26
- Tuffreau, A. 1982. The transition Lower/Middle Palaeolithic in Northern France. In Ronen, A. (ed.), *The Transition from Lower to Middle Palaeolithic and the Origin of Modern Man*, 137–49. Oxford: British Archaeological Reports 5151
- Tuffreau, A. 1995. The variability of Levallois technology in northern France and neighbouring areas. In Dibble & Bar-Yosef (eds) 1995, 413–27
- Turner, H., Kuiper, J.G.J., Thew, N., Bernasconi, R., Rüetschi, J., Wüthrich, M. & Gosteli, M. 1998. *Atlas der Mollusken der Schweiz und Liechtensteins*. Neuchâtel: Fauna Helvetica 2/Centre suisse de cartographie de la faune
- Van Peer, P. 1992. *The Levallois Reduction Strategy*. Madison: Prehistory Press
- Villa, P. 1982. Conjoinable pieces and site formation processes. *American Antiquity* 47, 276–90
- Warren, S.H. 1923a. The Elephas-antiquus bed of Clacton-on-Sea (Essex) and its flora and fauna. *Quarterly Journal of the Geological Society of London* 79, 606–36
- Warren, S.H. 1923b. The sub-soil flint flaking sites at Grays. *Proceedings of the Geologists' Association* 34, 38–42
- Warren, S.H. 1942. The drifts of south-western Essex. Parts I and II. *Essex Naturalist* 27, 154–79
- Wenban-Smith, F.F. 1995. The Ebbsfleet Valley, Northfleet (Baker's Hole). In Bridgland *et al.* (eds) 1995, 147–64
- Wenban-Smith, F., Gamble, C.S. & Apsimon, A. 2000. The Lower Palaeolithic site at Red Barns, Porchester, Hampshire: bifacial technology, raw material quality, and the organisation of archaic behaviour. *Proceedings of the Prehistoric Society* 66, 209–55
- West, R.G. 1969. Pollen analyses from interglacial deposits at Aveley and Grays, Essex. *Proceedings of the Geologists' Association* 80, 271–82
- West, R.G., Lambert, C.A. & Sparks, B.W. 1964. Interglacial deposits at Ilford, Essex. *Philosophical Transactions of the Royal Society of London* B247, 185–212
- Wheeler, A., 1969. *The Fishes of the British Isles and North West Europe*. London: Macmillan
- Whitaker, W. 1889. The Geology of London and Parts of the Thames Valley. Volume 1. *Memoir of the Geological Survey of Great Britain*. London: H.M.S.O.
- White, M.J. & Ashton, N.M. 2003. Lower Palaeolithic core technology and the origins of the Levallois method in NW Europe. *Current Anthropology* 44, 598–610
- White, M.J. & Jacobi, R.M. 2002. Two sides to every story: bout coupé handaxes revisited. *Oxford Journal of Archaeology* 21, 109–33
- Woodward, B.B. 1890. On the Pleistocene (non-marine) Mollusca of the London District. *Proceedings of the Geologists' Association* 11, 335–87
- Wymer, J.J. 1968. *Lower Palaeolithic Archaeology in Britain, as represented by the Thames Valley*. London: John Baker
- Wymer, J.J. 1985. *The Palaeolithic Sites of East Anglia*. Norwich: Geobooks
- Wymer, J.J. 1999. *The Lower Palaeolithic Occupation of Britain*. Salisbury: Trust for Wessex Archaeology